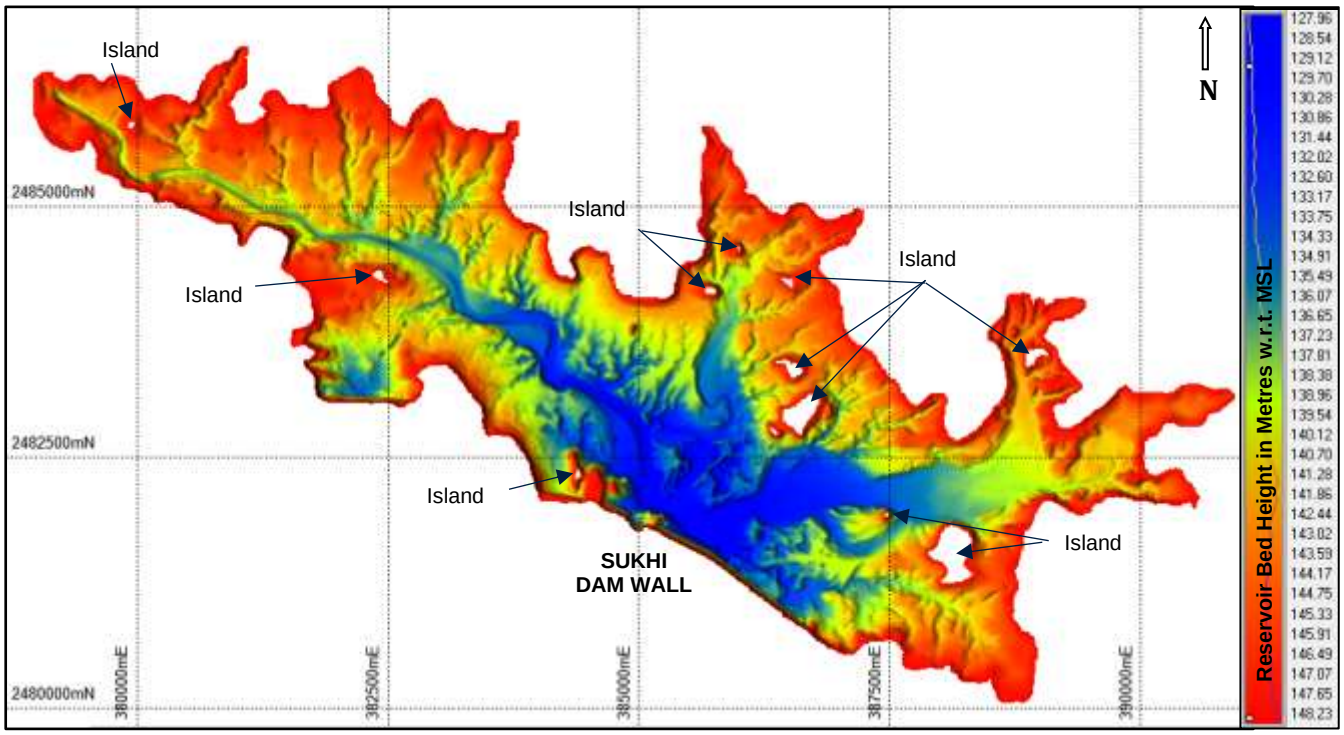

Providing Services for Conducting Bathymetric Survey of Reservoirs of Central Gujarat Under National Hydrology Project

Survey Results of Sukhi Reservoir Location | Central Gujarat

JHYD20-174630-Volume 8-Sukhi Reservoir/R1 [01] | 11 November 2021

Final Report

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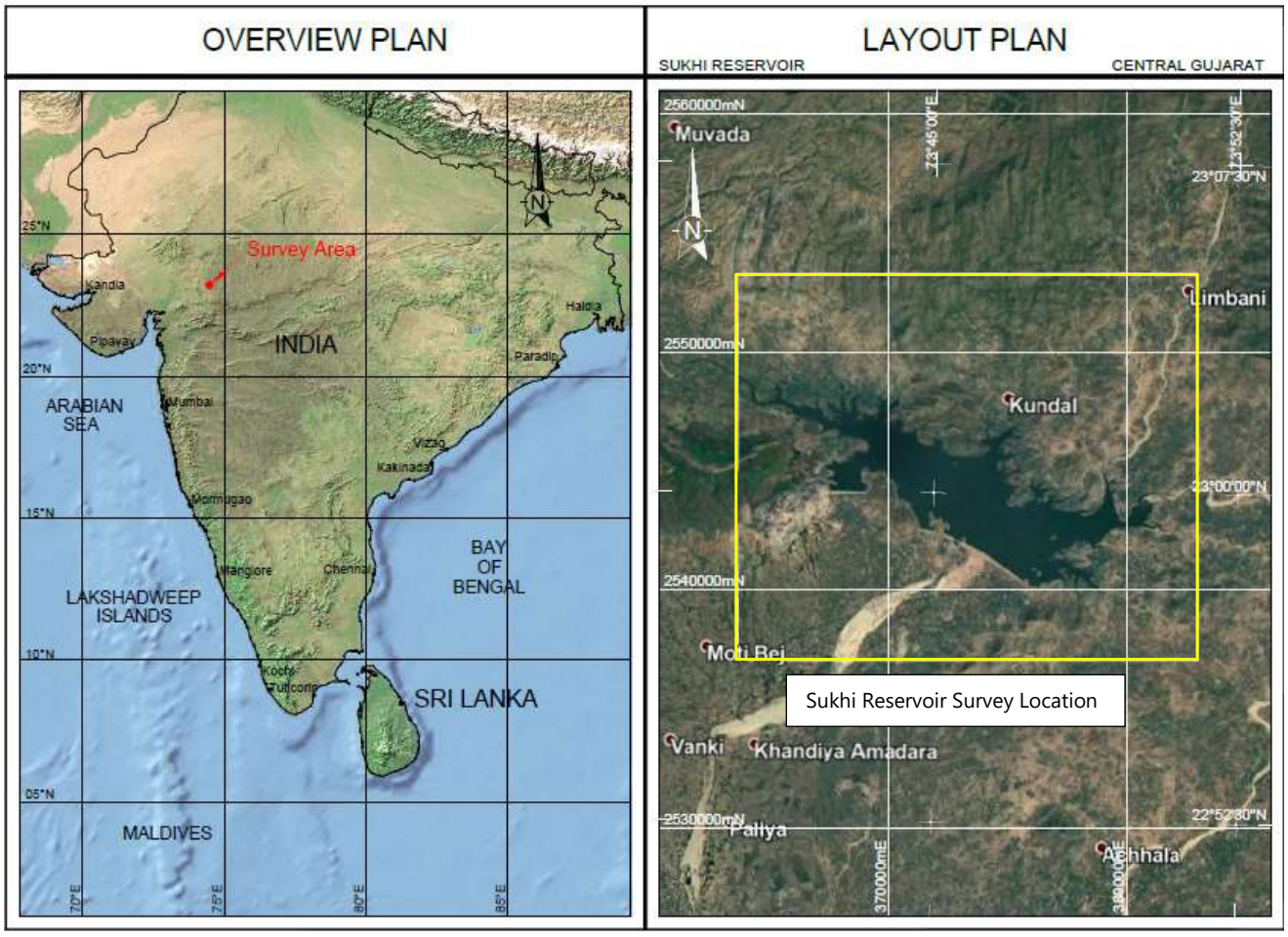
LOCATION MAP



EXECUTIVE SUMMARY

Survey Overview– Sukhi Reservoir Location	
Preamble:	The Gujarat State Government is implementing World Bank assisted national hydrology project. This project aims to improve the planning, development, and management of water resources, as well as flood forecasting and reservoir operations in real-time. Various activities, including Sediment survey, Water Quality monitoring have been planned under this project. Water Resources department have evolved a comprehensive plan for periodic assessment of reservoir storage capacity and sedimentation of eleven (11) reservoirs. In this regard, **Narmada Water Resources, Water Supply and Kalpsar Department/ Government of Gujarat** contracted **Fugro Survey (India) Pvt. Ltd. (FSINPVT)** to carry out the Bathymetry and Topography survey. Fugro's scope of work consist of Bathymetry and Topography survey at the eleven (11) reservoirs In order to complete the scope, the survey was carried out in two passes at Sukhi reservoir location; • Pass 1: Bathymetry / Hydrographic Survey. • Pass 2: Topographical Survey
Data Acquisition:	**FSINPVT** mobilised their bathymetry and topographical survey team and equipment along with survey boat 'Polaris' in the months of March - May 2021 and June - July 2021 respectively, in order to acquire survey data as per mutually agreed scope and relevant survey specifications.
Survey Location	Sukhi Reservoir, Sagdhara-Khos village, Pavi Jetpur Taluka, Chhota Udepur District, Gujarat.
Survey Geodesy:	The survey was conducted in WGS 84 datum, Universal Transverse Mercator (UTM) Projection, Zone 43 N, CM 075°E.
Scope Compliance & Meets Client's objectives:	FSINPVT performed this survey methodically as per the scope of work defined in the contract and the results obtained have met the client's objectives in following areas: ▪ To assess the reservoir storage capacity; ▪ To assess the variations in the reservoir capacity; ▪ To estimate and study sedimentation behaviour in horizontal zones and vertical zones, namely dead storage, live storage and flood storage; ▪ To upgrade Elevation–Area-Capacity tables / curves of reservoir at regular intervals; ▪ To create historical database for further water resources usage planning.
Accuracy and Reliability	The accuracy of the data logged was ensured by calibrating each and every sensor deployed in the current survey. Statistical techniques were applied during the execution of the survey to ensure that the results of survey conform to the agreed levels of accuracy and precision.
Tidal Corrections	All raw water depths were reduced to reservoir water levels. The water level heights or reservoir water levels w.r.t. MSL were observed for the entire survey period and the same was used to calculate the reservoir bed heights w.r.t. MSL.

Survey Findings – Sukhi Reservoir Location	
Reservoir Bed Heights	In general, lowest reservoir bed level was found at the upstream face of the dam and it becomes less deeper as we go further upstream from the dam face. Lowest reservoir bed level recorded during bathymetry survey was 128.0 m (385 379 mE, 2 481 928 mN) w.r.t. MSL.
Area Capacity Survey (2021)	Elevation Area Capacity table and curve of Sukhi reservoir was prepared based on bathymetry and topography survey data acquired at 25 m line spacing and 25 m x 25 m grid interval respectively. The processed xyz data was used to prepare DTM. Capacity and areas at various elevations from lowest bed level (128.0 m) to FRL (147.82 m) was calculated using GIS software.
Elevation area capacity details	In comparison with 1987 Original Project data, the present survey results indicate that the gross storage capacity has decreased.
Loss in gross storage capacity (w.r.t. 1987)	As per 2021 survey results, the loss in Gross storage capacity w.r.t. 1987 or volume of sediment deposited in the Sukhi reservoir is 3.234 Mm^3.
Loss in live storage capacity (w.r.t. 2013)	In comparison with 2013 survey results the 2021 survey results indicate increase in live storage capacity in the Sukhi reservoir. The increase in live storage is 2.986 Mm^3.
Trap efficiency & Sedimentation Index	Trap Efficiency and sedimentation Index calculated for Sukhi reservoir as per methodology give in IS 12182-1987 is 97% and 6.938 x 10^{10} sec^2/m respectively
Sedimentation rate	The rate of siltation in Sukhi reservoir is 0.095 Mm^3/year
Average rate of siltation	The observed rate of siltation in the Sukhi reservoir during the 34 year life span (1987 – 2021), works out to 2.310 Ha m/100 sq km/year.
Annual % loss	The annual % loss in gross storage capacity for Sukhi reservoir during the 34 year life span is 0.053% and hence, the reservoir is classified as “Insignificant category” as per IS 12182 (1987).

CONTENTS

1.	**Introduction**	**1**
1.1	General	1
1.2	Study Area	2
1.3	Geology of Study Area	5
1.4	Soil Types	5
1.5	Land use pattern	5
1.6	Sukhi Reservoir Characteristics	6
1.7	Project Objectives	7
1.8	Scope of Work	7
1.8.1	Pass 1: Bathymetry / Hydrographic Survey	8
1.8.2	Pass 2: Topographical Survey	8
1.9	Survey Execution	8
1.10	Reference Documents	8
1.11	Deliverables	8
2.	**Survey Specifications and Resources**	**9**
2.1	Survey Geodesy	9
2.2	Horizontal Control	9
2.3	Vertical Control / Water Level Corrections	10
2.4	Accuracy and Precision of Results	11
2.5	Survey Personnel Deployed	11
2.6	Equipment Deployed	12
2.7	Survey Vessel	12
2.8	Survey Database Used	13
3.	**Survey Data Acquisition**	**14**
3.1	Survey planning, Preparation & Transportation to Site	14
3.2	Equipment Setup Configuration and Calibration	14
3.3	Field Calibration and Verifications	14
3.3.1	Heading Sensor Alignment	14
3.3.2	Navigation System – DGNSS	15
3.3.3	Sound Velocity Measurements	15
3.3.4	Heave Compensator	15
3.3.5	Single Beam Echosounder	15
3.4	Data Acquisition and Online Quality Control	16
3.4.1	On-line QC of Data Logged	16
3.5	Topography Survey Control of Work	17
3.5.1	RTK Verification	17
3.5.2	RTK Position Comparison	17

3.5.3 Topographical Survey Methodology 17
3.6 Survey Coverage and Scope Completion 19
4. Data Processing and Interpretation 20
4.1 Navigation and Positioning 20
4.2 Bathymetry Data Processing 20
4.3 Creating Digital Terrain Model (DTM) 21
4.4 Development of Area Capacity Curves 21
4.5 Sedimentation in Different Zones of Reservoir 22
4.6 Charting the Results of Bathymetry and Topography Data 23
5. Survey Results – Sukhi Reservoir 24
5.1 Reservoir Bed Heights 24
5.2 Elevation Area Capacity Curve (2021) 29
5.3 Comparison of Elevation Area Capacity Details 33
5.4 Sedimentation in Reservoir 46
6. Conclusions 54
7. References 55

APPENDICES

Appendix A Diary of Events
Appendix B Survey Vessel Sensor Offsets
Appendix C Equipment Layout Diagram
Appendix D Results of Field Calibrations / Verifications
Appendix E Benchmark Descriptions
Appendix F List of Charts

TABLES

Table 1.1: Client Supplied Sukhi Reservoir Salient Features 6
Table 1.2: Sukhi Reservoir details for Bathymetry and Topography Survey 7
Table 1.3: Reference Documentation 8
Table 2.1: Geodetic Datum, Projection Parameters 9
Table 2.2: Observed Reservoir Water Level Heights at Sukhi Reservoir 10
Table 2.3: List of Survey Personnel – Bathymetry Survey 'Polaris' 11
Table 2.4: List of Survey Personnel – Topography Survey 11
Table 2.5: List of Personnel – Onshore Project Management and Data QC 11
Table 2.6: Survey Equipment / Systems Deployed for Bathymetry Survey in Polaris 12
Table 2.7: Survey Equipment / Systems Deployed for Topographical Survey 12
Table 3.1: Results of Positioning System Verification 15
Table 3.2: Summary of Single Beam Echosounder Calibration Results by 'Bar Check' Method 16
Table 3.3: Results of RTK Position Comparison 17
Table 5.1: Elevation Area Capacity table at every 0.1 m interval starting from lowest bed level to FRL for the Survey Year 2021 29
Table 5.2: Comparison of Elevation Capacity details of 2021, 1999 and 1982 data 33
Table 5.3: Comparison of Live Storage Capacity details of 1987 (Original), 2012-2013 and 2021 survey data 41
Table 5.4: Sedimentation in Sukhi Reservoir based on 1987 (Original) and 2021 survey data 46
Table 5.5: Trap Efficiency and Sedimentation Index for Sukhi Reservoir 46
Table 5.6: Sedimentation Volumes from Surveys of Previous Years of 1987 and 2021 (Gross Storage Capacity) 47
Table 5.7: Sedimentation in Sukhi Reservoir based on 1987 (Original), 2013, and 2021 survey data 47
Table 5.8: Sedimentation Volumes from Surveys of Previous Years of 1987, 2013 and 2021 (Live Storage Capacity) 48
Table 5.9: Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval 48
Table 5.10: Summary of previous survey (Live Storage Capacity) 53

FIGURES

Figure 1.1: Narmada basin showing major tributaries – Drainage and sub- basins (India-WRIS, 2014) and Satellite Image of Sukhi Reservoir (Google Earth) 4
Figure 2.1: Survey boat Polaris 12
Figure 3.1: Sukhi Dam Temporary Benchmark (SUKHI-TBM) 18
Figure 3.2: Temporary Benchmark 6 (TBM-06) 19
Figure 4.1: Reservoir Bed Height Calculation w.r.t. MSL 20
Figure 4.2: Sedimentation in different zones of reservoir (Ref: IS 5477-Part 1,1999) 22
Figure 5.1: Image showing gridded SBES Bathymetry and topography data (superimposed with satellite imagery) of reservoir bed heights in metres from lowest bed level to FRL 25
Figure 5.2: Shaded Relief Image showing gridded SBES Bathymetry and topography data of reservoir bed heights in metres from lowest bed level to FRL. 26
Figure 5.3: 3D view of Sukhi Reservoir 27

Figure 5.4: Photographs A, B, C and D showing the northern, eastern, north-western, and southern parts within Sukhi Reservoir respectively 28
Figure 5.5: Elevation Area Capacity Curve (2021) of Sukhi Reservoir 32
Figure 5.6: Comparison of Elevation Area capacity curves of Sukhi Reservoir for 1987(Original) and 2021 surveys 40
Figure 5.7: Comparison of Live capacity curves of Sukhi Reservoir for 1987(Original), 2012-2013 and 2021 surveys 45

LIST OF ABBREVATIONS

BM	Benchmark
Ch	Channel
CM	Central Meridian
CVT	Calibration, Verification & Test
DF	Dual Frequency
DGNSS	Differential Global Navigation Satellite System
DPR	Daily Progress Report
FBF	Fugro Binary Format
FRL	Full Reservoir Level
FSINPVT	Fugro Survey (India) Private Limited
FSL	Full Supply Level
ft	Feet
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
Ha	Hectare
HSE	Health, Safety and Environment
km	kilometre
m	metre
M ft^3	Millions cubic feet
M m^3	Millions cubic meter
MDDL	Minimum Draw Down Level
m/s	meter per second
ms	milliseconds
MSL	Mean Sea Level
OEM	Original Equipment Manufacturer
QA/QC	Quality Assurance / Quality Control
QMS	Quality Management System
Rel	Release
Rev	Revision
RL	Reference Level
SBES	Single beam Echosounder
Sr	Senior
SoW	Scope of Work
UTM	Universal Transverse Mercator
WGS	World Geodetic System
w.r.t	With respect to

UNITS

UTM grid coordinates and all linear measurements are reported in metres [m].

Angular values are reported in degrees (°).

Time and dates are reported as "18:00 on 16 February 2020

1. Introduction

1.1 General

Reservoirs originated by the construction of dams, is essential for the sustainable health and welfare of civilizations since it supplies water for human consumption, irrigation and energy production. Furthermore, dam reservoirs are used for recreation, navigation and they provide safety in the downstream valleys against extreme flood events and droughts (Bengtsson et al., 2012). All reservoirs are subjected to sedimentation which, without adequate prevention and mitigation counter-measures, threatens their sustainability.

Reservoir sedimentation is the gradual accumulation of the incoming sediment load from a river. This accumulation is a serious problem in many parts of the world and has severe consequences for water management, flood control, and production of energy. Sedimentation affects the safety of dams and reduces energy production, storage, discharge capacity and flood attenuation capabilities. It increases loads on the dam and gates, damages mechanical equipment and creates a wide range of environmental impacts (Schleiss et al., 2016).

Reservoir sedimentation is a process of erosion, transportation, deposition and compaction of sediments carried into reservoirs formed and contained by dams. In unregulated, mature rivers with stable catchments, sediment processes are relatively balanced. Construction of a dam decreases flow velocities, initiating or accelerating sedimentation.

Most of the world's reservoirs are in the continuous sediment accumulation stage. Many were designed by estimating sedimentation rates in order to provide a pool with sufficient volume to achieve a specified design life. However, this design life is typically far less than what is actually achievable. Therefore, managing reservoirs to achieve a full sediment balance is essential in order to maximize their lives. As every year sediment gets deposited in dead storage and in live storage of the reservoir, it has long and short range impact on the storage capacity of reservoir (Schellenberg et al., 2017). Correct assessment of the reservoir storage capacity is essential for assessing useful life of the reservoir as well as optimum reservoir operation schedule.

The Gujarat State Government is implementing World Bank assisted national hydrology project. This project aims to improve the planning, development, and management of water resources, as well as flood forecasting and reservoir operations in real-time. Various activities, including Sediment survey, Water Quality monitoring have been planned under this project. Water Resources department have evolved a comprehensive plan for periodic assessment of reservoir storage capacity and sedimentation of eleven (11) reservoirs.

In this regard, **Narmada Water Resources, Water Supply and Kalpsar Department/ Government of Gujarat** contracted **Fugro Survey (India) Pvt. Ltd. (FSINPVT)** to carry out the Bathymetry and Topography survey. Fugro's scope of work consist of Bathymetry and Topography survey at the eleven (11) reservoir as specified by Client.

These survey services comprised of the provision of suitable personnel and equipment in order to obtain, interpret and report on the bathymetry and topography within the survey area. In order to complete the scope, the survey was carried out in two passes at Sukhi reservoir;

Pass 1: Bathymetry / Hydrographic Survey;

Pass 2: Topographical Survey.

The bathymetry survey work was performed from the shallow draft boat 'Polaris'.

The survey reports are submitted in separate volumes for each reservoir location. This report covers **Bathymetry / Hydrographic and Topographical survey results for Sukhi Reservoir location.**

1.2 Study Area

The present study area falls under Narmada basin (Figure 1.1) which covers an area of 92,672.42 km^2 (GIS based calculated area) spreading across four states of Madhya Pradesh, Gujarat, Maharashtra and Chhattisgarh. Narmada basin is sub-divided into three sub-basins viz. Narmada upper sub-basin, Narmada middle sub-basin and Narmada lower sub-basin. Basin drainage and sub-basin boundary is given in Figure 1.1. Narmada upper sub-basin (46.61% of total basin area) consists of 71 watersheds, Narmada middle sub-basin (43.78% of total basin area) consists of 63 watersheds and Narmada lower sub-basin (9.61% of total basin area) consists of 16 watersheds (India WRIS, 2014).

The Narmada basin covers an area of 9894 km^2 (approximately 9% of the total basin area) in Gujarat.

Narmada is the largest west flowing river of the peninsula India. It rises from a Kund near Amarkantak, in the Anuppur district of Madhya Pradesh, at an elevation of about 1057 m w.r.t. MSL in the Maikala range. This river forms the traditional boundary between North India and South India and flows through Madhya Pradesh, Maharashtra and Gujarat between Vindhya and Satpura hill ranges before falling into the Gulf of Cambay in the Arabian Sea about 10 km north of Bharuch. The total length of the river from the head to its outfall into the Arabian Sea is 1,333 km. For the first 1085 km it runs in Madhya Pradesh and thereafter forms the common boundary between Madhya Pradesh and Maharashtra for 39 km, and Maharashtra and Gujarat for 43 km. In Gujarat State it stretches for 166 km (India WRIS, 2014).

There are total 41 tributaries of the Narmada River. Out of these, eight (08) important tributaries join the river from right bank and eleven (11) important tributaries joins from the left bank (India WRIS, 2014).

Karjan and Orsang rivers are the left and right bank tributaries of Narmada in the lower plains.

Sukhi River is a tributary of Orsang river and flows in northwest direction and is fed with seasonal rainwater. The major part of its catchment area is in the eastern Gujarat, with 79% of its area in Chhota Udepur district, 15% in Dahod district, 1 % in Panchmahal district, and remaining 5% in Jhabua district in adjoining state of Madhya Pradesh. The catchment area is mostly agricultural and forest land, and a significant part of the catchment falls within the Ratanmahal wildlife sanctuary (Kumar et al., 2019).

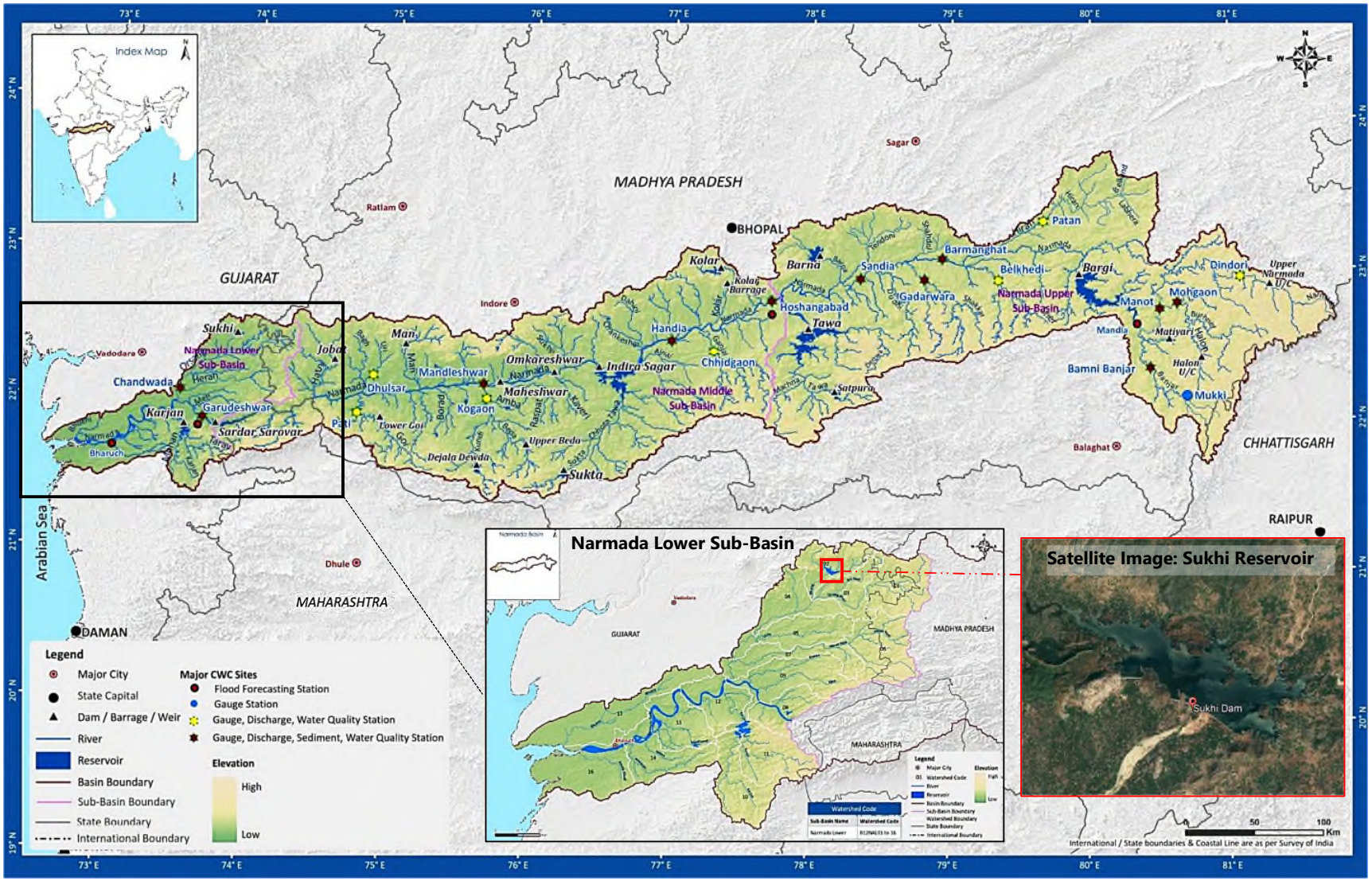


Figure 1.1: Narmada basin showing major tributaries – Drainage and sub- basins (India-WRIS, 2014) and Satellite Image of Sukhi Reservoir (Google Earth)

1.3 Geology of Study Area

The rocks of the Chhota Udepur district shows an age from Proterozoic to Recent but a striking features of the district stratigraphy is the total absence of Paleozoic, and the development of only the uppermost Mesozoic rocks. The south westerly extended Precambrian basement of Peninsular India, the oldest rocks of Proterozoic age, are exposed in eastern and north eastern part of the district. Post Cretaceous sediments & major volcanic rocks rest over this south westerly extended Precambrian basement. Post Cretaceous sediments, Infratrappean and Intratrappean are exposed as scattered inliers while younger volcanic rocks unit as Deccan traps are well represented and so are the Tertiary and Quaternary, though the Tertiary records are not complete and fully exposed.

The older Pre-Champaner Gneissic Complex is exposed in the south-eastern part of the fold belt around Jetpur and Chhota Udepur regions (Das and Saha, 2001). This complex consists of quartz - muscovite - felspathic gneiss, biotite granite gneiss, banded gneiss, patches of muscovite schist (±kyanite), sillimanite-bearing muscovite schist, garnetiferous biotite schist and gneisses (Das et al., 2009).

At the Sukhi dam site, rock type such as Granite, Pegmatite veins, Gneiss and Mica schists with Pegmatite were encountered.

1.4 Soil Types

The soils of Chhota Udepur district are broadly categorized into four types viz. (i) Hard Black Soil, (ii) Medium Black Soil, (iii) Sandy loam Soil and (iv) Saline Soil.

The present survey area is located in Jetpur Pavi taluka within Chhota Udepur district where deep black, medium black to loamy sand (Goradu) soils are observed.

1.5 Land use pattern

The Chhota Udepur district has a geographical area of 343.606 ('000 Ha.) which comprises cultivable area of 165.430 ('000 Ha.), forest area of 75.304 ('000 Ha.), cultivable wasteland of 15.358 ('000 Ha.) and other fallow land of 38.867 ('000 Ha.).

1.6 Sukhi Reservoir Characteristics

The Sukhi reservoir is constructed over the Sukhi river. Sukhi major irrigation scheme was executed between the years 1978 and 1987 and consists of earthen and masonry dam.

Salient features of the Sukhi reservoir and dam are tabulated below.

Table 1.1: Client Supplied Sukhi Reservoir Salient Features

Characteristics	Feature
Reservoir name	Sukhi Reservoir
Name of Dam	Sukhi Dam
Purpose	Irrigation
Name of River	Sukhi
River Basin	Narmada (Narmada Lower Sub-Basin)
Village	Sagdhara-Khos
Taluka	Pavi Jetpur
District	Chhota Udepur from 2013 (formerly in Vadodara district)
State	Gujarat
Year of commencement of construction work	1978
Year of completion	1987
Hydrology	
Total Catchment Area	411.81 km^2
Mean annual rainfall	1053 mm
Annual Yield	217.10 Mm^3
Maximum observed flood	3610.00 Cumecs
Reservoir Details	
Top bund level.	152.50 m
High Flood Level (H.F.L.)	148.30 m
Full Reservoir Level (F.R.L.)	147.82 m
Spillway crest level	139.59 m
Minimum draw down level (MDDL)	135.0 m
Gross storage capacity	178.47 Mm^3 (1987)
Live Storage	167.14 Mm^3 (1987)
Dead Storage	11.33 Mm^3 (1987)
Area at full reservoir level	29.04 km^2
Dam Details	
Type of Dam	Earthen dam and Masonry spillway
Total Volume Content:	
Concrete	0.0327 Mm^3
Masonry	0.102 Mm^3

Characteristics	Feature	
Earthwork	4.579 Mm^3	
Bed Rock	Granite, Gneiss and Mica-schists	
Maximum height above the lowest point of foundation	38 m	
Length of the dam	4254.66 m	
Height of the dam	26.50 m	
Spillway Details		
Length	149.66 m (249 m including NOF)	
Type	Ogee	
Type, size and number of Gates	Radial, 12.50 m x 8.23 m, 10 nos.	
Maximum discharge	5964.3 m^3/s	
Canal Details	Left Bank Canal	Right Bank Canal
Length (km)	3.06	38.07
Discharge Capacity (m^3/s)	4.56	12.96

1.7 Project Objectives

Primarily the main objective of the survey was to:

- Assess the reservoir storage capacity;
- Assess the variations in the reservoir storage capacity;
- Create historical database for further water resources usage planning.
- However, the main objective of the bathymetry survey was to:
- Estimate and study the sedimentation behaviour of reservoirs in different zones including horizontal zones throughout the reservoirs as well as vertical zones namely:
    a) Dead storage
    b) Live storage
    c) Flood storage
- Upgrade Elevation-Area-Capacity tables / curves of reservoirs at regular intervals.

Table 1.2 provides bathymetry and topography survey area details for Sukhi reservoir.

Table 1.2: Sukhi Reservoir details for Bathymetry and Topography Survey

Name of Dam / Reservoir	Actual Area (km^2) surveyed	
	Bathymetry Survey	Topography Survey
Sukhi	13.82	12.61

1.8 Scope of Work

To achieve the above objective, Fugro carried out survey for eleven (11) reservoir areas in two (02) passes. The scope of work undertaken for Sukhi reservoir is as follows:

1.8.1 Pass 1: Bathymetry / Hydrographic Survey

The scope of work conforms bathymetry survey for total area of 13.82 km^2 was completed.

The following scope of work was undertaken in-order to achieve client objectives:

- Bathymetry / Hydrographic survey work was conducted using echosounder for assessment of reservoir capacity and sedimentation at Sukhi reservoir of Gujarat.
- Survey lines were run at 25 m segment line spacing and along the survey line continuous data of 25 m x 25 m grid point were captured so that each and every point is included. Additional survey lines were executed as and when required.
- DGNSS positioning system, Dual frequency single beam echosounder system along with associated Navigational system were deployed on all the survey lines.

1.8.2 Pass 2: Topographical Survey

Topographical survey was carried out using Total station and equivalent levelling instruments. The total area covered in topographical survey was 12.61 km^2. Following scope of work was undertaken in order to achieve client objectives:

- Topographical survey was conducted to facilitate hydrographic survey so as to fill up the gaps between MWL area and reservoir submergence area till current water level for assessment of reservoir capacity and sedimentation at the reservoir locations.
- Topographical survey was carried out from FSL to present water level of reservoir, with sufficient overlap with hydrographic survey for preparing overall contour map of reservoir.
- The area not covered through hydrographic survey upto maximum water level (MWL), was surveyed by taking levels at 25 m interval along range lines laid at 25 m interval (25 m x 25 m grid).

1.9 Survey Execution

The survey boat 'Polaris' was mobilized at Sukhi reservoir location to carry out the survey. Survey operations were executed as per the mutually agreed survey execution schedule.

1.10 Reference Documents

Table 1.3: Reference Documentation

Sl/No.	Document Name	Document identity
1	FSINPVT Quote / Contract	NOA No. WRIDn/SK/NOA/1588/2020 Dated 09 November 2020
2	FSINPVT Survey Procedure	JHYD20-174630/SP/P0/Rev.0 dated 01 December 2020

1.11 Deliverables

Final report and Charts / Drawings to be delivered as per the contract, as listed in Appendix F to this Report, have been duly submitted. Details of the Charts accompanying this report are also placed at Appendix F.

2. Survey Specifications and Resources

The bathymetry / hydrographic survey and topography survey conformed to the following mutually agreed scope of work and were conducted as per the methodology described in the standard work instruction by FSINPVT.

2.1 Survey Geodesy

The survey was conducted in WGS84 Datum and grid coordinates in terms of Universal Transverse Mercator (UTM) projection (Zone 43 N, CM 075° E) as per client's instruction. The details of the Geodetic parameters are as follows:

Table 2.1: Geodetic Datum, Projection Parameters

Global Positioning System Geodetic Parameters	
Datum:	World Geodetic System 1984
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	1/f = 298.257 223 563
Map Projection:	Universal Transverse Mercator
Grid System:	UTM Zone 43 N;
Central Meridian:	075° 00′ 00″ East
Latitude of Origin:	0° 00′ 00″ North
False Easting:	500 000 m
False Northing:	0 m
Scale factor on Central Meridian:	0.9996
Units:	Metre
Notes: • The Client has specified the above Datum and Transformation parameters to be used for this survey. • Fugro's Starfix software suite always uses WGS84 as the primary datum for all geodetic calculations.	

2.2 Horizontal Control

Spatial Dual was used for positioning the survey vessel during this survey. Spatial Dual is a rugged GPS aided inertial navigation system that provides accurate position, velocity, acceleration and orientation under the most demanding conditions. It combines temperature calibrated accelerometers, gyroscopes, magnetometers and a pressure sensor with a dual antenna RTK GNSS receiver. They are coupled in a sophisticated fusion algorithm to deliver accurate and reliable navigation and orientation.

The computer running Starfix NG was used for navigation, data logging and online quality control of the survey data.

2.3 Vertical Control / Water Level Corrections

All vertical levels were reduced to respective water level references. The water level heights or reservoir water levels w.r.t. MSL were observed for the entire survey period and the same was used to calculate the reservoir bed height. Observed reservoir water level heights is tabulated below:

Table 2.2: Observed Reservoir Water Level Heights at Sukhi Reservoir

Date	Observed Reservoir Water Level Heights w.r.t. MSL at Sukhi Reservoir [m]
03-04-2021	144.45
04-04-2021	144.40
05-04-2021	144.32
06-04-2021	144.25
07-04-2021	144.19
08-04-2021	144.10
09-04-2021	144.06
10-04-2021	144.03
11-04-2021	143.94
12-04-2021	143.89
13-04-2021	143.84
14-04-2021	143.80
15-04-2021	143.74
16-04-2021	143.68
17-04-2021	143.60
18-04-2021	143.60
19-04-2021	143.53
20-04-2021	143.49
21-04-2021	143.48
22-04-2021	143.39
23-04-2021	143.38
24-04-2021	143.32
25-04-2021	143.28
26-04-2021	143.19
27-04-2021	143.14
28-04-2021	143.09
29-04-2021	143.03
30-04-2021	142.96
01-05-2021	142.94
02-05-2021	142.86

Date	Observed Reservoir Water Level Heights w.r.t. MSL at Sukhi Reservoir [m]
03-05-2021	142.84
04-05-2021	142.78

2.4 Accuracy and Precision of Results

The accuracy of the data logged was ensured by calibrating each and every survey sensor deployed for the current survey, for eliminating systematic errors or bias. Internationally accepted survey work practices were adopted for carrying out such calibrations, sensor alignments and field verifications.

The quality of the data logged was monitored on-line using Fugro's on-line QC tools and ensured it met the agreed accuracy and precision levels. At the data processing, charting and reporting stages, the results of survey were further analysed and checked to ensure that they conformed to the agreed levels of accuracy and precision. The precision (or the repeatability) of the results of survey were controlled by adopting 'Statistical' techniques.

2.5 Survey Personnel Deployed

Following FSINPVT staffs were associated to bathymetry survey for this project.

Table 2.3: List of Survey Personnel – Bathymetry Survey 'Polaris'

Bathymetry Survey Personnel	
Personnel Name	**Function**
Arpit Bose	Party Chief / Surveyor
Mathiyazhagan V.	Engineer
Sunil Singh	Polaris Operator

Following FSINPVT staffs were associated to topography survey for this project.

Table 2.4: List of Survey Personnel – Topography Survey

Topography Survey Personnel	
Personnel Name	**Function**
Arunabha Chakraborty+ Survey Assistants	Topography Survey Team

Following onshore FSINPVT staffs were associated to this project.

Table 2.5: List of Personnel – Onshore Project Management and Data QC

Onshore Project Management and Data QC	
Rahul Patkar	Service Line Manager
Vikas Walanj/Anantha Krishnan	Project Manager
R.B. Jayaraman	Client Deliverable Manager
Avijit Nag	Survey Manager
G.N. Hariharan	Chief Geophysicist
Avinash Vasudevan	Reporting Manager

Onshore Project Management and Data QC	
Prashant Mishra	Reporting Project Supervisor
K. Srinivas	Data Centre Manager

2.6 Equipment Deployed

Following equipment and systems were deployed for the survey work. The equipment setup and configuration diagram on the survey boat Polaris is placed at Appendix C to this document.

Table 2.6: Survey Equipment / Systems Deployed for Bathymetry Survey in Polaris

Equipment / System	Description / Make / Model/Resolution /Accuracies
Software / Navigation	Starfix.NG PC based data acquisition and survey vessel navigation package.
Positioning	Trimble BX-992 & Spatial Dual Receivers
Heading Sensor	Spatial Dual
Motion Sensor	Spatial Dual
Sound Velocity	Odom DigiBar Pro
Single beam Echosounder	Echotrac E20 Dual Frequency Single Beam Echosounder

Table 2.7: Survey Equipment / Systems Deployed for Topographical Survey

Equipment / System	Description / Make / Model/Resolution /Accuracies
Land Survey	GNSS RTK LYNX H6 System along with accessories and consumables.

2.7 Survey Vessel

Shallow draft boat 'Polaris' was used to carry out the bathymetry / hydrographic survey.

Figure 2.1: Survey boat Polaris

2.8 Survey Database Used

Details of all existing engineering structures within the survey area, as supplied by the Client and interface boundaries drawn between land and water body, shallow patches taken from Google Earth images, were used as a background file in the navigation system during the entire tenure of survey.

- Client supplied FRL/FSL RL height – 147.82 m w.r.t. MSL
- Full Supply Level (FSL) – 147.82 m w.r.t. MSL
- Water line – 143.60 m approximately.

3. Survey Data Acquisition

3.1 Survey planning, Preparation & Transportation to Site

The bathymetry survey equipment and personnel with survey boat 'Polaris' arrived at Sukhi reservoir location on 30 March 2021 and equipment was mobilised on-board the survey boat on 1 -2 April 2021.

After field testing / verification / calibration of all survey equipment bathymetry survey was carried out and completed on 05 May 2021. Refer Appendix A to this document for diary of events.

The topography survey equipment and personnel arrived at Sukhi reservoir location and commenced survey on 24 June 2021. The topography survey was completed on 24 July 2021.

3.2 Equipment Setup Configuration and Calibration

All survey equipment was installed and configured on-board the survey boat as per the 'Equipment Layout Diagram' placed at Appendix C to this document.

The location of the various survey sensors on the survey boat is given in the 'Vessel Offset Diagram' placed at Appendix B to this document.

3.3 Field Calibration and Verifications

All equipment used for the survey work were calibrated and bench tested prior to their mobilisation for this task. In addition, after installation on the survey vessels, extensive calibration, verification and tests were carried out in the field before deploying them for actual data acquisition. Standard survey methods were used for carrying out these calibrations / verifications and data acquisition, as described in the following paragraphs.

Refer to Appendix D of this document for the 'Results of the Calibrations / Verifications of Survey Sensors'.

3.3.1 Heading Sensor Alignment

Vessel heading was obtained onboard 'Polaris' from Spatial Dual. Spatial dual features dual antenna moving baseline RTK. This enables it to provide extremely accurate heading both at rest and at movement. It's a great option for situations where magnetic heading isn't possible due to interference or where extra precision is required. The system was tested at FSINPVT workshop prior to mobilization for the survey. The performance of the system was found to be satisfactory during the period of survey.

3.3.2 Navigation System – DGNSS

The Positioning System on board 'Polaris' was Spatial Dual. Position observations were done at Sukhi reservoir benchmark locations, using Trimble BX-992 and Spatial Dual receiver. Refer Appendix E for Benchmark description and Appendix D for details on position system verification results. The performance of the system was found to be satisfactory. Summary of the results of the position system verification is tabulated below:

Table 3.1: Results of Positioning System Verification

Positioning System Verification Results With BX-992 and Spatial Dual Receiver (Polaris)						
WGS 84, UTM Projection, CM 075°E, Zone 43N						
Sensor	Serial No.	Easting (mE)	Northing (mN)	Latitude	Longitude	Ellipsoidal Height (m)
Trimble BX-992	025-00009611	385 058.568	2 481 832.21	22°26'19.916"N	73°52'58.916"E	95.665
Spatial Dual	025-272968	385 058.43	2 481 832.172	22°26'19.914"N	73°52'58.911"E	95.806
Difference		0.138	0.038	--	--	-0.141

3.3.3 Sound Velocity Measurements

Sound Velocity in the water column was measured in the survey area at regular intervals using sound velocity probe. Sound velocity profiles (cast) thus generated were used during post processing of SBES data.

3.3.4 Heave Compensator

Spatial dual is a high precision source for heave information. The system was tested at FSINPVT workshop prior to mobilization for the survey. The performance of the system was found to be satisfactory during the period of survey.

3.3.5 Single Beam Echosounder

Echotrac E20 dual frequency single beam echosounder was used for measuring water depths within the survey corridor. The echo sounder system was bench tested at FSINPVT workshop prior to mobilization for the survey. The echo sounder transducer was vertically side mounted on the survey boat and its draft below the waterline was measured and recorded. Heave compensator was connected to the echo sounder receiver. The echo sounder system was interfaced with the Starfix NG navigation and survey system for logging the depth vs position data. Sound velocity within water column was measured on a regular basis using sound velocity profiler and average sound velocity was entered in the top side unit of the echo sounder.

Table 3.2: Summary of Single Beam Echosounder Calibration Results by 'Bar Check' Method

Summary of SBES Calibration Results on-board 'Polaris'			
Date	SBES Sensor Type	Average (m)	Standard Deviation
3 April 2021	Echotrac E20 SBES	0.00	0.0034

3.4 Data Acquisition and Online Quality Control

On successful completion of mobilization and Calibration, Verification & Testing of all equipment as per the standard work practices, the survey data acquisition commenced as per the project plan to achieve the objectives of survey.

Navigation System, Heading and Bathymetry

The navigation data and vessel heading from the spatial dual, was logged continuously and monitored using the Starfix NG navigation suite. The survey data was logged in Fugro Binary Format (.FBF).

Event Markings

The on-line computer system was interfaced for closure to the analogue traces on the survey vessel. Event marks corresponding to position fixes were generated automatically from the on-line Navigation Computer interface at regular intervals of 25 m across the ground.

Survey Run-Line Logs

Survey lines were planned as per scope of work and digital pre-plots for the area was prepared prior to commencement of survey. These lines were run on the navigational computer while doing the survey and this enabled the Navigator to guide the boat along the planned survey line all the time. A survey line log was maintained which consists the particulars about the surveyed line, Date, Time, Session Number, Event Number, KP, Sensors Deployed and all the significant events occurred during the survey.

3.4.1 On-line QC of Data Logged

FSINPVT follows standard procedures and has standard formats for documenting the Quality Control of acquired data for each sensor deployed during the survey. Experienced operators were constantly monitoring the real time data quality as the survey progressed. A log of profiles was maintained, and quality of data was noted. Re-shoots of survey lines were carried out as and when required.

All computers connected to the Navigation network were synchronized with the GPS (high precision) 1PPS time signal by means of the Starfix Timing Module, allowing all data to be time stamped.

The quality of data being recorded was constantly monitored in real time and fine-tuned to obtain the best quality. The data / record obtained from each survey sensor such as Navigation, Heading, SBES and Spatial dual were quality checked and an extract of the same were made available for verification and confirmation to proceed further.

3.5 Topography Survey Control of Work

3.5.1 RTK Verification

The RTK system verification was carried out by 'Static Observations' for 30 minutes at Sukhi Dam Temporary Benchmark (SUKHI-TBM) and Temporary Benchmark 6 (TBM-06).

3.5.2 RTK Position Comparison

The RTK observed position at Temporary Benchmark 6 (TBM-06) was compared with Trimble BX-992 Receiver position. Results of the comparison is tabulated below:

Table 3.3: Results of RTK Position Comparison

Sensor	Model No.	Easting (mE)	Northing (mN)
TBM-06 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009611	385 058.568	2 481 832.210
RTK Rover 1	Lynx-H6	385 058.394	2 481 832.283
Difference		0.174	-0.073
TBM-06 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009611	385 058.568	2 481 832.210
RTK Rover 2	Lynx-H6	385 058.421	2 481 832.279
Difference		0.147	-0.069
TBM-06 (WGS 84, UTM Projection, CM 075°E, Zone 43N)			
Trimble BX-992	025-00009611	385 058.568	2 481 832.210
RTK Rover 3	Lynx-H6	385 058.414	2 481 832.288
Difference		0.154	-0.078

Refer Appendix D for RTK comparison details.

3.5.3 Topographical Survey Methodology

The area not covered under hydrographic survey i.e., between the existing water level at the time of survey up to Full Reservoir Level (FRL)- 147.820 m has been carried out by topography survey method.

The topography survey was carried out using GNSS RTK Lynx-H6 system. The RTK system consist of two units i.e., Base receiver and Rover receiver. Corrected GPS signals are transmitted in real time from a base receiver at a known location to one or more rover receivers. Following steps were carried out while commencing and executing the topography survey operations:

- Components of Base and Rover receivers were setup at benchmark locations.
- Tripod was setup at base station i.e., at the temporary benchmark location (SUKHI-TBM) established by Fugro by levelling method and thereafter the tripod was levelled and the RTK base station was configured.
- The rover receiver along with RTK pole was installed at TBM-06 location. Static observation was carried out subsequently as part of verification.
- The Base receiver is installed at SUKHI-TBM and configured the system with known coordinates and elevation (levelling carried out by Fugro). The rover receiver position and elevation are verified by setting up the system at TBM-06.
- The level or height transfer for temporary Benchmark established by Fugro were carried out w.r.t. client supplied reference level. The levelling report is placed in Appendix E.
- Thereafter survey commenced by placing the rover receiver at 25 m grid interval and logging the position (easting, northing) and the elevation in relation to the base.
- Whenever the radio RTK coverage between rover receiver and base receiver is reduced, new check points were created and the base receiver was shifted to this newly created check point.
- Above procedure was followed and survey completed from the existing water line till achieving the HFL mark.

Figure 3.1: Sukhi Dam Temporary Benchmark (SUKHI-TBM)

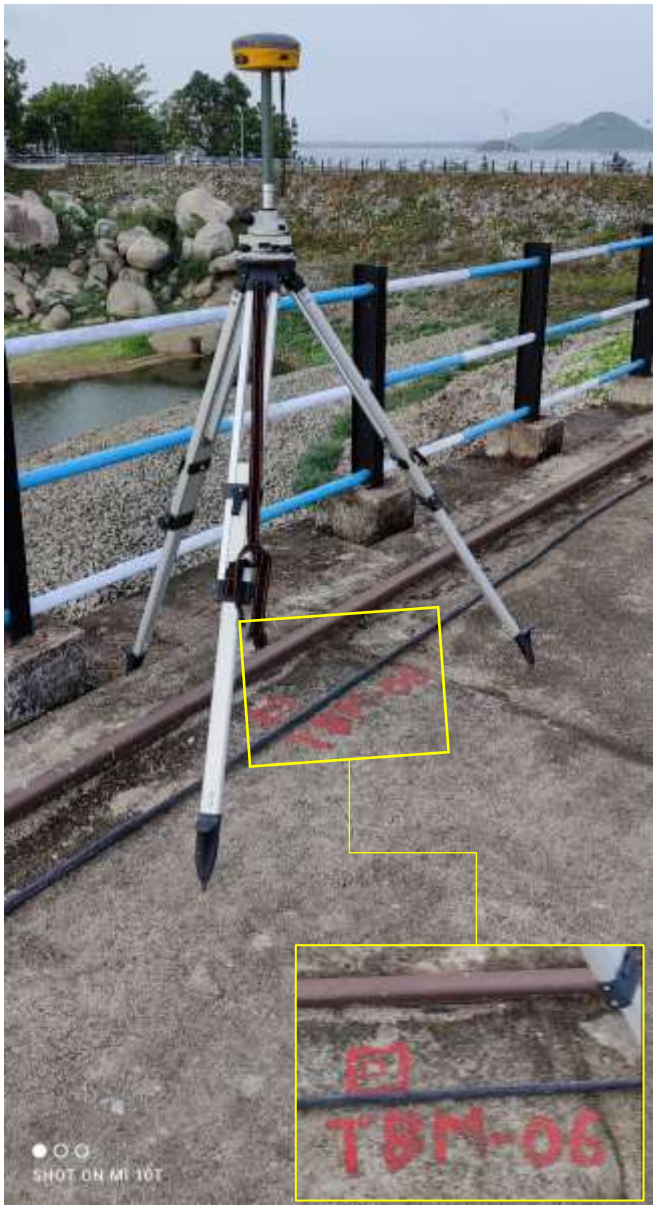


Figure 3.2: Temporary Benchmark 6 (TBM-06)

3.6 Survey Coverage and Scope Completion

FSINPVT carried out the bathymetry and topography survey operation methodically to meet the client's objectives from this survey.

- The survey work was carried out on par with the mutually agreed scope and objectives mentioned in the Section 1.6 of this document.
- Survey scope from existing water level up to the Full Reservoir Level (FSL)- 147.820 m, was achieved by undertaking topography survey.

All the bathymetric survey lines were run at appropriate spacing i.e., 25 m, so as to obtain data of 25 m x 25 m grid points.

4. Data Processing and Interpretation

4.1 Navigation and Positioning

- The survey data was logged in Fugro Binary format (FBF), and processed using the Starfix.Proc software. Heading, motion and position data were processed and checked to ensure good data quality. The position data for the various survey sensors were processed and plotted to allow commencement of the interpretation of the bathymetry data.
- The measured offsets for all survey sensors were entered into the navigation system and processed using Starfix.Proc to enable track charts to be plotted and 'corrected' navigation files to be integrated with other sensor data at a later stage. These included:
    - GPS position absolute of the primary & secondary positioning systems.
    - Common Reference Point

4.2 Bathymetry Data Processing

- SBES bathymetry data was reduced to MSL, applying observed Reservoir Water Level / Height heights recorded at Dam. (Refer Figure 4.1)
- The data was filtered, cleaned, and combined to create geographically positioned bathymetric data set that has been corrected for MSL and sound speed.
- Starfix.Workbench & Mproc was used to quality check the data.

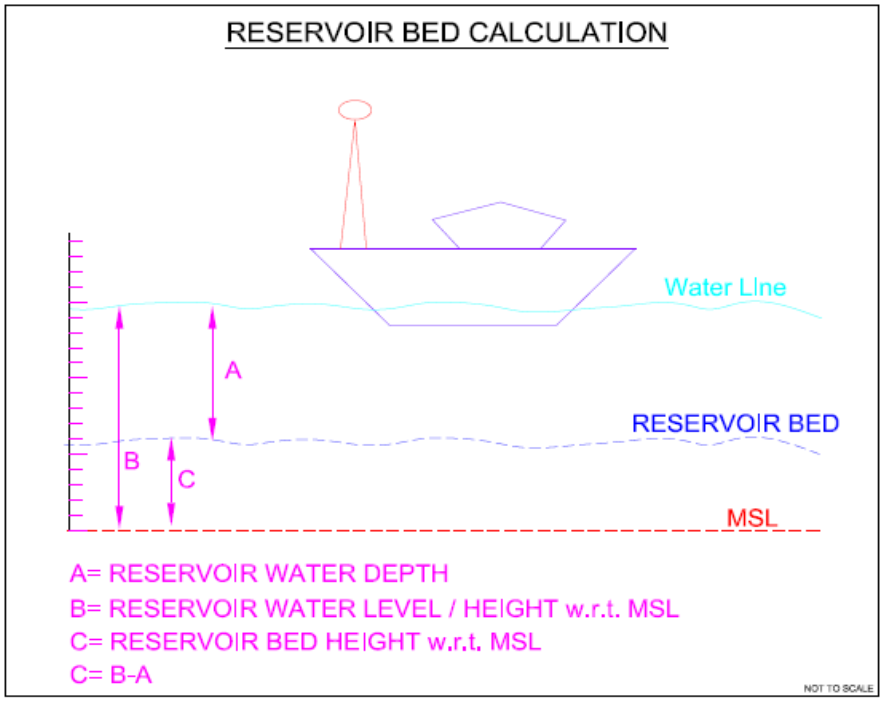


Figure 4.1: Reservoir Bed Height Calculation w.r.t. MSL

4.3 Creating Digital Terrain Model (DTM)

The bathymetric data and topographic data were then combined to create a vector point shapefile in GIS software. The boundary of the reservoir was then digitized around the point shapefile. Two types of boundaries were constructed. First boundary is outside the reservoir and second type of boundary consisted of the boundary around islands in the reservoir. This point shapefile was then utilized for creation of DTM. The DTM for the reservoir can be created by use of various algorithms such as Kriging, Radial Basis function, Inverse Distance Weighting (IDW) method and local polynomial function. Among these various methods, IDW can give the best interpolation accuracy for reservoirs (Shiferaw and Abebe, 2020). IDW method is a weighted average interpolation method. For every grid node, the resulting value Z will be calculated using the formula as given in (1).

$$Z = \frac{\sum_{i=1}^{n} \frac{Z_i}{r_i^p}}{\sum_{i=1}^{n} \frac{1}{r_i^p}} \quad (1)$$

Where:

- Z_i is the known value at point i,
- r_i is the distance from grid node to point i,
- p is the weighting power,
- n is the number of points in Search Ellipse.

Therefore, in this study IDW method has been used for the interpolation for the creation of DTM. The DTM thus created was saved in Tiff format. The created DTM was smoothed by use of various filtering operations. Thereafter, the DTM was clipped through extract by mask operations using the mask of boundary shapefiles created before. The final DTM thus obtained after clipping the DTM was then used for further analysis.

Contour maps at 1 m interval was also prepared using the DTM in Starfix.Workbench software.

4.4 Development of Area Capacity Curves

Area Capacity curves are useful tools for operational and planning purposes such as water management and sediment monitoring. By comparing the area capacity curves at different times, the rate of sedimentation in the reservoirs can be determined. These curves show the capacity and surface area of the reservoir at an indicated elevation above the reference elevation level. The elevation area capacity curves are prepared using the DTM for the reservoir site. For, this study the reference elevation level used for the preparation of Area capacity curve is 128.00 m which is the lowest bed level for the reservoir and the maximum level considered is 147.820 m which is Full Reservoir Level (FRL) of the reservoir. The incremental value for elevation used for developing these curves is kept at 0.1 m. The surface area at the successive intervals was obtained in GIS software by intersecting the DTM with horizontal planes at an interval of 0.1 m starting from the zero-bed elevation till the MWL. The incremental volume (ΔV_i) between two contours was then calculated and integrated from bottom to specified

elevation to obtain the required capacity at specified elevation. The method and formula used for volume calculation is the cone formula given by the equation 2.

$$\Delta V = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) \quad (2)$$

Where, ΔV is the incremental volume between two successive elevations; h is the incremental height between two successive elevations; A1 and A2 are the areas of two successive elevations.

4.5 Sedimentation in Different Zones of Reservoir

The sediment entering into the reservoir carried by the flowing river from the upstream catchments get deposited in the reservoir with the passage of time and reduces the live as well as dead storage capacity of the reservoir. This causes the bed level near the dam to rise. Live storage is from the level MDDL to FRL. Dead storage is from Bed Level to MDDL. Gross storage is from Bed Level to FRL. The sedimentation in different zones of reservoir is shown in Figure 4.2.

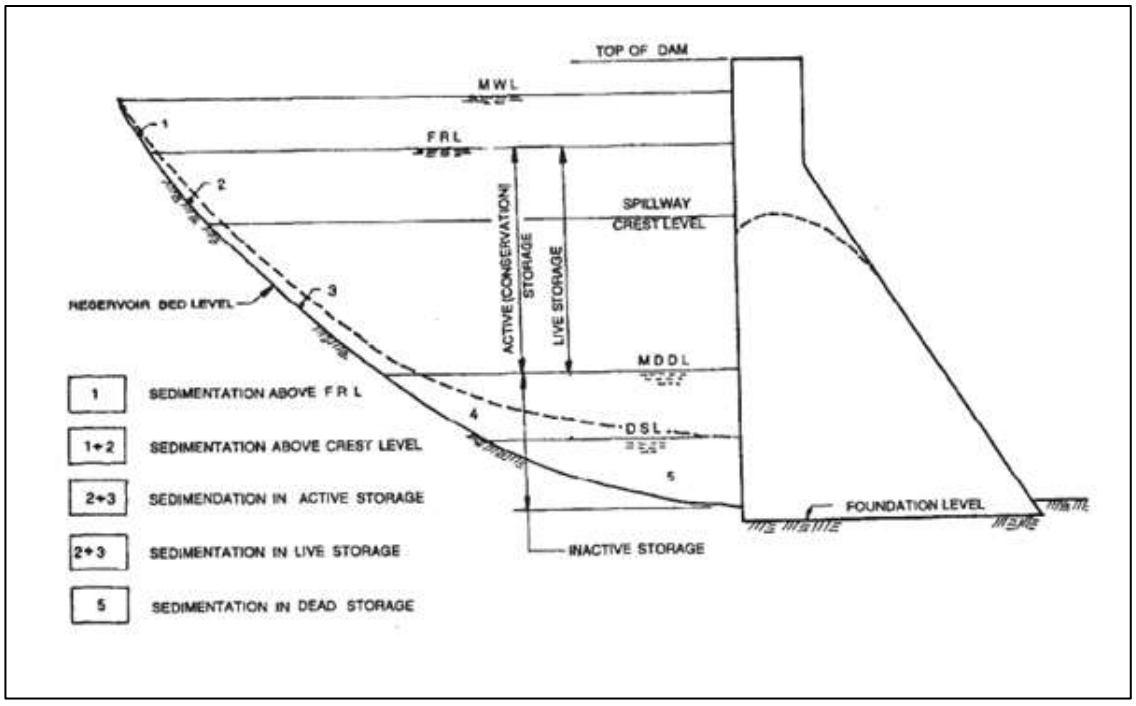


Figure 4.2: Sedimentation in different zones of reservoir (Ref: IS 5477-Part 1,1999)

The trap efficiency and the silt index has been calculated based on the methodology given in IS 12182, 1987. The gross capacity of reservoir as per present survey at FRL is 175.236 Mm^3 and client supplied Mean Annual inflow is 217.10 Mm^3. The values of trap efficiency were calculated using Brune's curve for the capacity inflow ratio for the reservoir. The silt index is calculated as the ratio of period of retention and flow velocity in the reservoir. The details of the calculations of period of retention and flow velocity are given in standard codes such as IS 12182, 1987. The values for Sukhi reservoir are shown in Table 5.4.

At last, sedimentation volumes are compared with sedimentation volumes from previous year surveys (if available) and rate of sedimentation, loss of capacity as well as annual loss percentage is computed and compared with the values of previous years (if available) to arrive at meaningful conclusions. The sedimentation quantities as well as loss of storage capacities, rate of siltation as well as trap efficiency and sedimentation index are shown in Section 5.3.

The Sedimentation rate and Annual % loss is calculated using the equations (3) and (4)

$$\textit{Sedimentation rate (Ha m/ 100 Sq km/year)} = \frac{100 * \text{loss of gross capacity (Ha m)}}{\text{Catchment Area (Sq km)} * \text{Number of years between the surveys}} \quad (3)$$

$$\textit{Annual \% loss} = \frac{\text{Annual Sedimentation rate (M cu m)}}{\text{Original Gross capacity of reservoir (M cu m)}} \; x \; 100 \quad (4)$$

4.6 Charting the Results of Bathymetry and Topography Data

- Chart showing reservoir bed heights are provided for the current survey at 1:12000 scale.
- Chart showing contour map at 1 m interval for Sukhi reservoir is also provided at 1:12000 scale.
- Chart showing reservoir bed relief image prepared from bathymetry and topography survey data is provided at 1:12000 scale.
- L-section of the reservoir and C-section at 100 m interval are provided as soft copy.

The results of the survey were submitted as per the documents in the 'List of Deliverables' placed at Appendix F.

5. Survey Results – Sukhi Reservoir

Survey results are detailed in the following sections. The following text should be read in conjunction with the Charts as listed in Appendix F to this document.

Data acquisition for Sukhi reservoir was carried out up to Full Supply Level (FSL)/Full Reservoir Level (FRL) of 147.820 m.

5.1 Reservoir Bed Heights

The lowest reservoir bed level was found at the upstream face of the dam & it becomes less deeper as we go further upstream from the dam face.

The reservoir topography was uneven with reservoir bed level ranging 128.0 m to 147.82 m w.r.t. MSL.

The reservoir bed tends to get shallower as we go further towards north-west, north, east and south-east directions away from the reservoir dam wall within the survey area. Reservoir area is spreading towards north west and east directions. At some of the places shallow patches / islands were observed within the surveyed area.

Lowest reservoir bed level recorded was 128.0 m (385 379 mE, 2 481 928 mN) w.r.t. MSL, within the survey area.

The following figures show the gridded bathymetry and topography data for the Sukhi reservoir.

Figure 5.1: Image showing gridded SBES Bathymetry and topography data (superimposed with satellite imagery) of reservoir bed heights in metres from lowest bed level to FRL

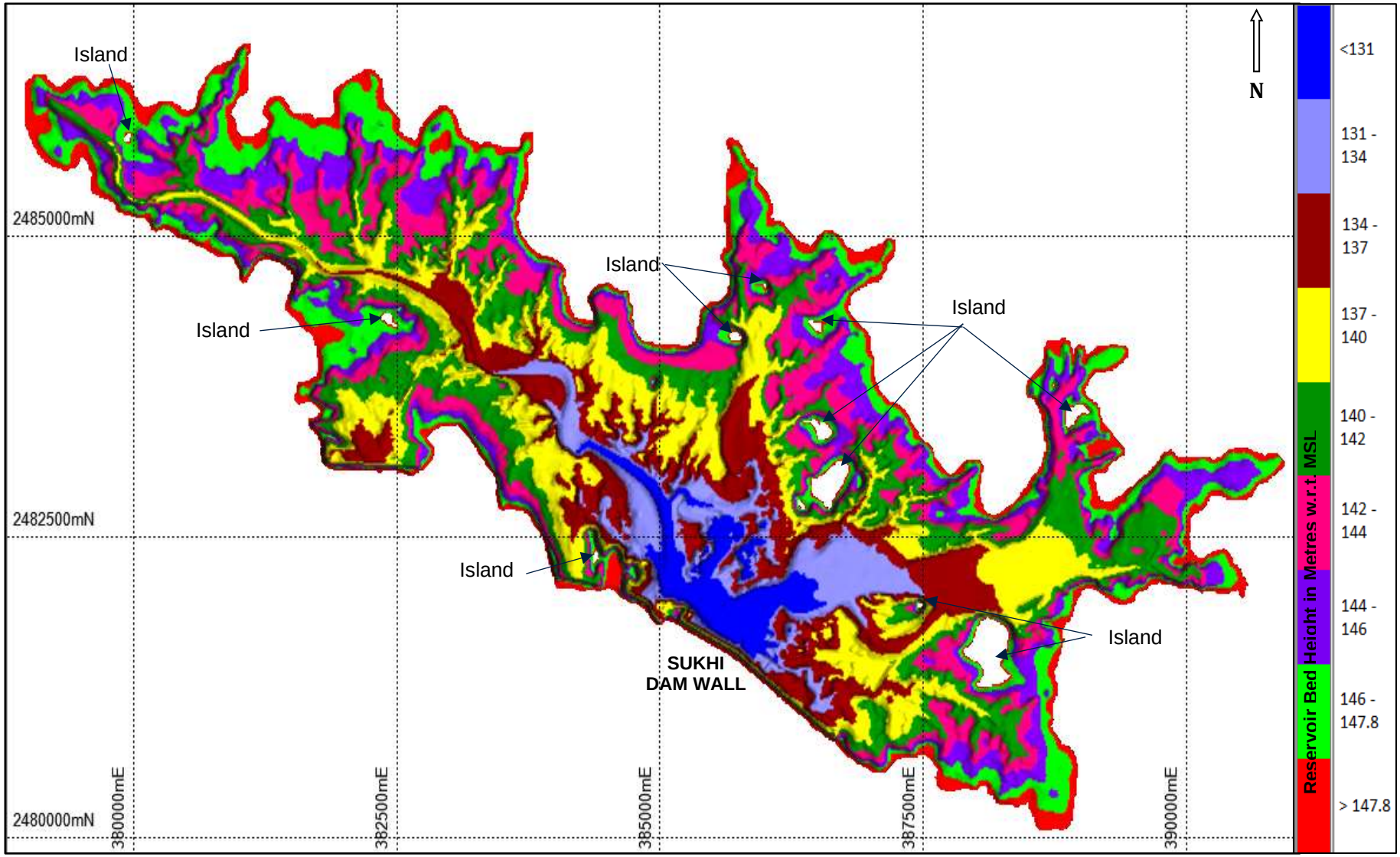


Figure 5.2: Shaded Relief Image showing gridded SBES Bathymetry and topography data of reservoir bed heights in metres from lowest bed level to FRL.

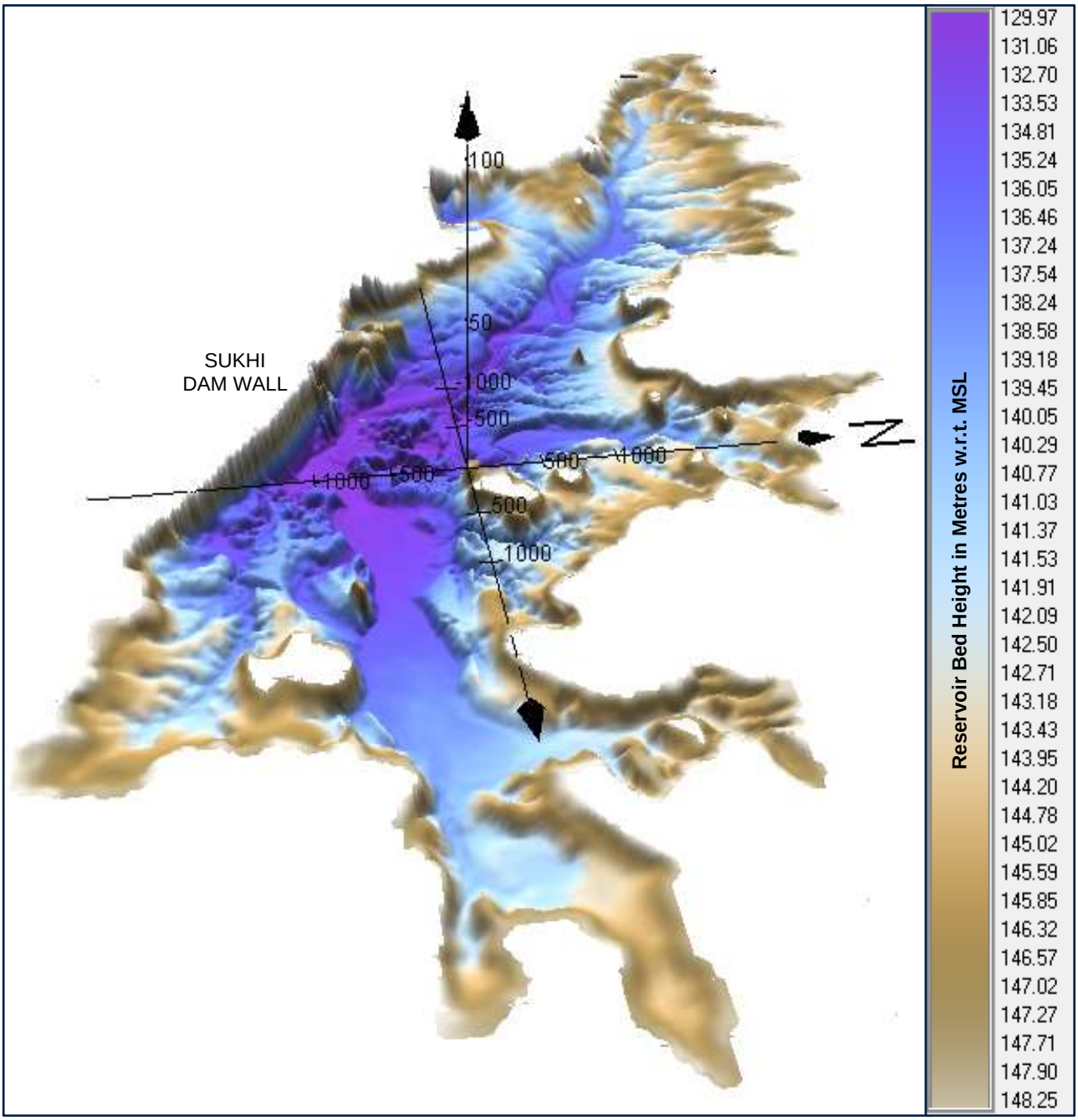


Figure 5.3: 3D view of Sukhi Reservoir

Photograph A: Northern part of Sukhi Reservoir (386590 mE, ,2484857 mN) with shallow water depth and submerged vegetation.

Photograph B: Eastern part of Sukhi Reservoir with shallow water depth.

Photograph C: North-western part of Sukhi Reservoir (381969 mE, 2484370 mN) with shallow water depth.

Photograph D: Southern part of Sukhi Reservoir (386880 mE 2481738 mN) showing rocky island.

Figure 5.4: Photographs A, B, C and D showing the northern, eastern, north-western, and southern parts within Sukhi Reservoir respectively

5.2 Elevation Area Capacity Curve (2021)

The area and capacity of the Sukhi reservoir was tabulated against the respective increasing elevation starting from lowest bed elevation (i.e., 128.00 m) up to 149.00 m (FRL is 147.82 m) at an increment of 0.1 m as shown in Table 5.1. Area capacity curve for Sukhi reservoir is shown in Figure 5.5.

Table 5.1: Elevation Area Capacity table at every 0.1 m interval starting from lowest bed level to FRL for the Survey Year 2021

Elevation Area Capacity Table (2021): Sukhi Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Gross Capacity [Mm^3]	Remarks
1	128.00	0.0001	0.00000	Bed level
2	128.10	0.0007	0.00004	-
3	128.20	0.0032	0.00022	-
4	128.30	0.011	0.001	-
5	128.40	0.024	0.003	-
6	128.50	0.037	0.006	-
7	128.60	0.051	0.010	-
8	128.70	0.075	0.016	-
9	128.80	0.098	0.025	-
10	128.90	0.123	0.036	-
11	129.00	0.164	0.050	-
12	129.10	0.211	0.069	-
13	129.20	0.241	0.092	-
14	129.30	0.276	0.117	-
15	129.40	0.308	0.147	-
16	129.50	0.337	0.179	-
17	129.60	0.367	0.214	-
18	129.70	0.399	0.252	-
19	129.80	0.436	0.294	-
20	129.90	0.472	0.339	-
21	130.00	0.510	0.388	-
22	130.10	0.551	0.441	-
23	130.20	0.592	0.498	-
24	130.30	0.631	0.560	-
25	130.40	0.672	0.625	-
26	130.50	0.712	0.694	-
27	130.60	0.751	0.767	-
28	130.70	0.793	0.844	-
29	130.80	0.832	0.926	-
30	130.90	0.869	1.011	-
31	131.00	0.911	1.100	-
32	131.10	0.954	1.193	-

Elevation Area Capacity Table (2021): Sukhi Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Gross Capacity [Mm^3]	Remarks
33	131.20	1.003	1.291	-
34	131.30	1.051	1.393	-
35	131.40	1.099	1.501	-
36	131.50	1.151	1.613	-
37	131.60	1.203	1.731	-
38	131.70	1.254	1.854	-
39	131.80	1.305	1.982	-
40	131.90	1.359	2.115	-
41	132.00	1.415	2.254	-
42	132.10	1.475	2.398	-
43	132.20	1.534	2.549	-
44	132.30	1.589	2.705	-
45	132.40	1.640	2.866	-
46	132.50	1.694	3.033	-
47	132.60	1.742	3.205	-
48	132.70	1.793	3.381	-
49	132.80	1.840	3.563	-
50	132.90	1.886	3.749	-
51	133.00	1.933	3.940	-
52	133.10	1.981	4.136	-
53	133.20	2.031	4.337	-
54	133.30	2.085	4.542	-
55	133.40	2.141	4.754	-
56	133.50	2.199	4.971	-
57	133.60	2.261	5.194	-
58	133.70	2.324	5.423	-
59	133.80	2.386	5.658	-
60	133.90	2.447	5.900	-
61	134.00	2.511	6.148	-
62	134.10	2.578	6.402	-
63	134.20	2.649	6.664	-
64	134.30	2.720	6.932	-

Elevation Area Capacity Table (2021): Sukhi Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Gross Capacity [Mm^3]	Remarks
65	134.40	2.794	7.208	-
66	134.50	2.871	7.491	-
67	134.60	2.954	7.782	-
68	134.70	3.038	8.082	-
69	134.80	3.123	8.390	-
70	134.90	3.212	8.706	-
71	135.00	3.308	9.032	MDDL
72	135.10	3.412	9.368	-
73	135.20	3.520	9.715	-
74	135.30	3.636	10.073	-
75	135.40	3.756	10.442	-
76	135.50	3.870	10.824	-
77	135.60	3.983	11.216	-
78	135.70	4.090	11.620	-
79	135.80	4.190	12.034	-
80	135.90	4.287	12.458	-
81	136.00	4.389	12.891	-
82	136.10	4.496	13.336	-
83	136.20	4.608	13.791	-
84	136.30	4.714	14.257	-
85	136.40	4.816	14.733	-
86	136.50	4.927	15.221	-
87	136.60	5.045	15.719	-
88	136.70	5.168	16.230	-
89	136.80	5.294	16.753	-
90	136.90	5.414	17.288	-
91	137.00	5.535	17.836	-
92	137.10	5.661	18.396	-
93	137.20	5.789	18.968	-
94	137.30	5.913	19.553	-
95	137.40	6.037	20.151	-
96	137.50	6.158	20.760	-
97	137.60	6.282	21.382	-
98	137.70	6.408	22.017	-
99	137.80	6.534	22.664	-
100	137.90	6.659	23.324	-
101	138.00	6.782	23.996	-
102	138.10	6.905	24.680	-
103	138.20	7.028	25.377	-
104	138.30	7.156	26.086	-

Elevation Area Capacity Table (2021): Sukhi Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Gross Capacity [Mm^3]	Remarks
105	138.40	7.292	26.808	-
106	138.50	7.427	27.544	-
107	138.60	7.565	28.294	-
108	138.70	7.720	29.058	-
109	138.80	7.880	29.838	-
110	138.90	8.033	30.634	-
111	139.00	8.180	31.444	-
112	139.10	8.328	32.270	-
113	139.20	8.480	33.110	-
114	139.30	8.626	33.965	-
115	139.40	8.775	34.835	-
116	139.50	8.923	35.720	-
117	139.60	9.073	36.620	-
118	139.70	9.222	37.535	-
119	139.80	9.374	38.464	-
120	139.90	9.528	39.410	-
121	140.00	9.691	40.371	-
122	140.10	9.860	41.348	-
123	140.20	10.028	42.342	-
124	140.30	10.190	43.353	-
125	140.40	10.355	44.381	-
126	140.50	10.525	45.425	-
127	140.60	10.704	46.486	-
128	140.70	10.888	47.566	-
129	140.80	11.077	48.664	-
130	140.90	11.270	49.781	-
131	141.00	11.467	50.918	-
132	141.10	11.668	52.075	-
133	141.20	11.883	53.252	-
134	141.30	12.129	54.453	-
135	141.40	12.363	55.678	-
136	141.50	12.646	56.928	-
137	141.60	12.913	58.206	-
138	141.70	13.185	59.511	-
139	141.80	13.444	60.842	-
140	141.90	13.710	62.200	-
141	142.00	13.971	63.584	-
142	142.10	14.245	64.995	-
143	142.20	14.491	66.431	-
144	142.30	14.729	67.892	-

Elevation Area Capacity Table (2021): Sukhi Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Gross Capacity [Mm^3]	Remarks
145	142.40	14.959	69.377	-
146	142.50	15.167	70.883	-
147	142.60	15.371	72.410	-
148	142.70	15.564	73.957	-
149	142.80	15.754	75.523	-
150	142.90	15.938	77.107	-
151	143.00	16.112	78.710	-
152	143.10	16.275	80.329	-
153	143.20	16.433	81.964	-
154	143.30	16.588	83.616	-
155	143.40	16.747	85.282	-
156	143.50	16.906	86.965	-
157	143.60	17.073	88.664	-
158	143.70	17.228	90.379	-
159	143.80	17.383	92.110	-
160	143.90	17.535	93.855	-
161	144.00	17.690	95.617	-
162	144.10	17.842	97.393	-
163	144.20	18.000	99.185	-
164	144.30	18.160	100.993	-
165	144.40	18.325	102.818	-
166	144.50	18.484	104.658	-
167	144.60	18.642	106.514	-
168	144.70	18.809	108.387	-
169	144.80	18.971	110.276	-
170	144.90	19.132	112.181	-
171	145.00	19.298	114.102	-
172	145.10	19.466	116.041	-
173	145.20	19.621	117.995	-
174	145.30	19.777	119.965	-
175	145.40	19.932	121.950	-
176	145.50	20.089	123.951	-
177	145.60	20.251	125.968	-
178	145.70	20.421	128.002	-
179	145.80	20.588	130.053	-
180	145.90	20.753	132.120	-
181	146.00	20.926	134.203	-
182	146.10	21.099	136.305	-
183	146.20	21.277	138.423	-
184	146.30	21.456	140.560	-

Elevation Area Capacity Table (2021): Sukhi Reservoir				
Sr. No.	Elevation [m]	Area [km^2]	Gross Capacity [Mm^3]	Remarks
185	146.40	21.633	142.715	-
186	146.50	21.804	144.886	-
187	146.60	21.978	147.076	-
188	146.70	22.155	149.282	-
189	146.80	22.340	151.507	-
190	146.90	22.534	153.751	-
191	147.00	22.719	156.013	-
192	147.10	22.901	158.294	-
193	147.20	23.079	160.593	
194	147.30	23.255	162.910	-
195	147.40	23.423	165.244	-
196	147.50	23.594	167.595	-
197	147.60	23.764	169.963	-
198	147.70	23.943	172.348	
199	147.80	24.130	174.752	-
200	147.82	24.168	175.236	FRL
201	147.90	24.317	177.174	-
202	148.00	24.664	179.623	-
203	148.10	24.950	182.104	-
204	148.20	25.185	184.611	
205	148.30	25.390	187.139	-
206	148.40	25.550	189.686	-
207	148.50	25.684	192.248	-
208	148.60	25.802	194.822	-
209	148.70	25.911	197.408	
210	148.80	26.020	200.005	-
211	148.90	26.109	202.611	-
212	149.00	26.190	205.226	-

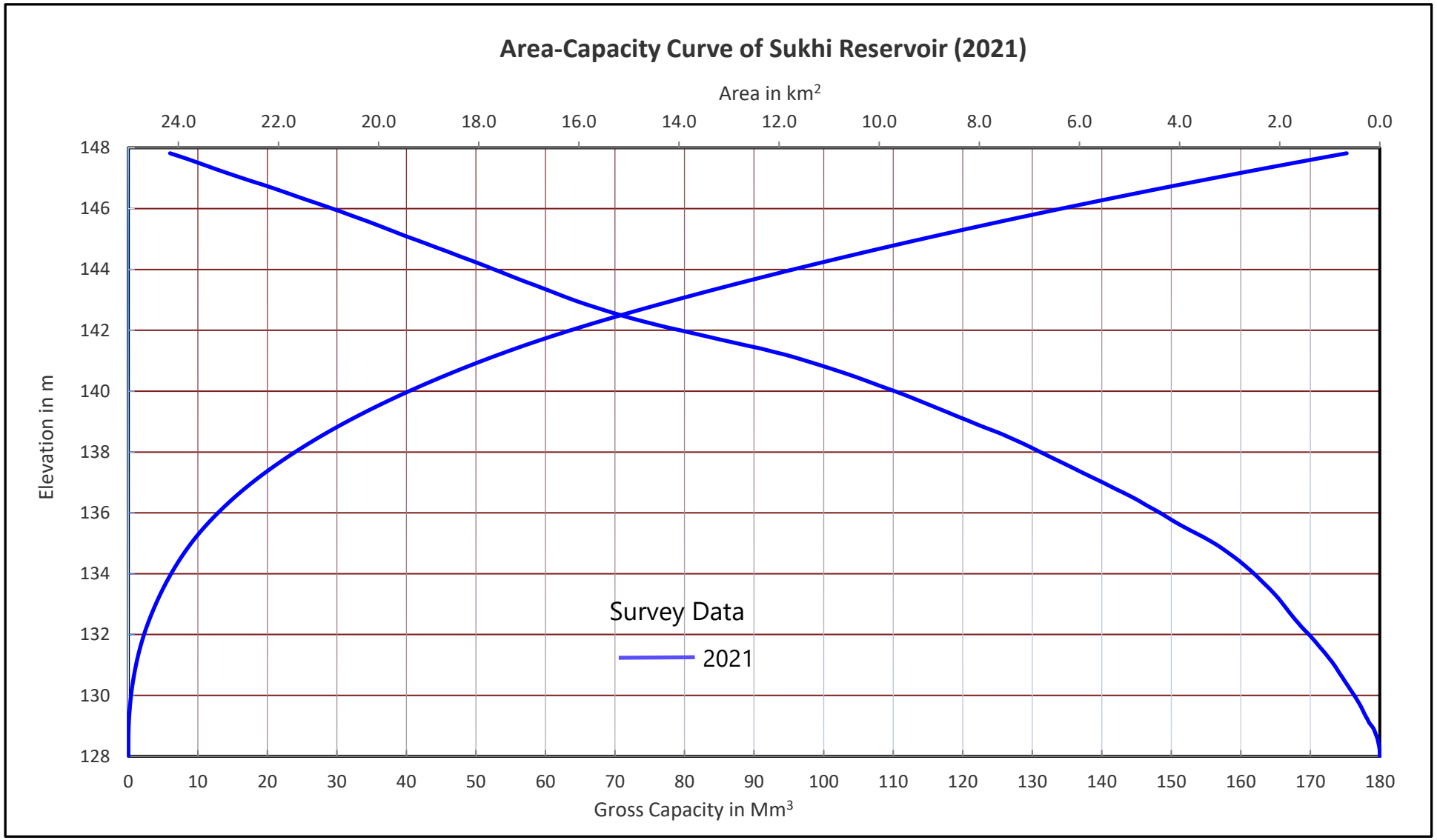


Figure 5.5: Elevation Area Capacity Curve (2021) of Sukhi Reservoir

5.3 Comparison of Elevation Area Capacity Details

Comparison of the elevation area capacity details for the year 2021 with the elevation area capacity for the previous year of 1987 (Original) is shown in Table 5.2. In addition, the comparison plots of elevation area capacity curves for the year 1987 and 2021 are shown in Figure 5.6.

In general, the 2021 survey results indicate that there is loss in gross storage capacity w.r.t. 1987 original project capacity.

Table 5.2: Comparison of Elevation Capacity details of 2021, 1999 and 1982 data

Sr. No	Elevation (w.r.t. MSL) [m]	1987 (Original)		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
1	128.00	-	-	0.000	0.00000
2	128.10	-	-	0.001	0.00004
3	128.20	-	-	0.003	0.00022
4	128.30	-	-	0.011	0.001
5	128.40	-	-	0.024	0.003
6	128.50	-	-	0.037	0.006
7	128.60	-	-	0.051	0.010
8	128.70	-	-	0.075	0.016
9	128.80	-	-	0.098	0.025
10	128.90	-	-	0.123	0.036
11	129.00	-	-	0.164	0.050
12	129.10	-	-	0.211	0.069
13	129.20	-	-	0.241	0.092
14	129.30	-	-	0.276	0.117
15	129.40	-	-	0.308	0.147
16	129.50	-	-	0.337	0.179
17	129.60	-	-	0.367	0.214
18	129.70	-	-	0.399	0.252
19	129.80	-	-	0.436	0.294
20	129.90	-	-	0.472	0.339
21	130.00	-	-	0.510	0.388
22	130.10	-	-	0.551	0.441
23	130.20	-	-	0.592	0.498
24	130.30	-	-	0.631	0.560

Sr. No	Elevation (w.r.t. MSL) [m]	1987 (Original)		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
25	130.40	-	-	0.672	0.625
26	130.50	-	-	0.712	0.694
27	130.60	-	-	0.751	0.767
28	130.70	-	-	0.793	0.844
29	130.80	-	-	0.832	0.926
30	130.90	-	-	0.869	1.011
31	131.00	-	-	0.911	1.100
32	131.10	-	-	0.954	1.193
33	131.20	-	-	1.003	1.291
34	131.30	-	-	1.051	1.393
35	131.40	-	-	1.099	1.501
36	131.50	-	-	1.151	1.613
37	131.60	-	-	1.203	1.731
38	131.70	-	-	1.254	1.854
39	131.80	-	-	1.305	1.982
40	131.90	-	-	1.359	2.115
41	132.00	-	-	1.415	2.254
42	132.10	-	-	1.475	2.398
43	132.20	-	-	1.534	2.549
44	132.30	-	-	1.589	2.705
45	132.40	-	-	1.640	2.866
46	132.50	-	-	1.694	3.033
47	132.60	-	-	1.742	3.205
48	132.70	-	-	1.793	3.381
49	132.80	-	-	1.840	3.563
50	132.90	-	-	1.886	3.749
51	133.00	-	-	1.933	3.940
52	133.10	-	-	1.981	4.136
53	133.20	-	-	2.031	4.337
54	133.30	-	-	2.085	4.542
55	133.40	-	-	2.141	4.754
56	133.50	-	-	2.199	4.971

Sr. No	Elevation (w.r.t. MSL) [m]	1987 (Original)		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
57	133.60	-	-	2.261	5.194
58	133.70	-	-	2.324	5.423
59	133.80	-	-	2.386	5.658
60	133.90	-	-	2.447	5.900
61	134.00	2.600	7.870	2.511	6.148
62	134.10	2.680	8.216	2.578	6.402
63	134.20	2.760	8.562	2.649	6.664
64	134.30	2.840	8.908	2.720	6.932
65	134.40	2.920	9.254	2.794	7.208
66	134.50	3.000	9.600	2.871	7.491
67	134.60	3.080	9.946	2.954	7.782
68	134.70	3.160	10.292	3.038	8.082
69	134.80	3.240	10.638	3.123	8.390
70	134.90	3.320	10.984	3.212	8.706
71	135.00	3.400	11.330	3.308	9.032
72	135.10	3.480	11.807	3.412	9.368
73	135.20	3.560	12.284	3.520	9.715
74	135.30	3.640	12.761	3.636	10.073
75	135.40	3.720	13.238	3.756	10.442
76	135.50	3.800	13.715	3.870	10.824
77	135.60	3.880	14.192	3.983	11.216
78	135.70	3.960	14.669	4.090	11.620
79	135.80	4.040	15.146	4.190	12.034
80	135.90	4.120	15.623	4.287	12.458
81	136.00	4.200	16.100	4.389	12.891
82	136.10	4.299	16.590	4.496	13.336
83	136.20	4.398	17.080	4.608	13.791
84	136.30	4.497	17.570	4.714	14.257
85	136.40	4.596	18.060	4.816	14.733
86	136.50	4.695	18.550	4.927	15.221
87	136.60	4.794	19.040	5.045	15.719
88	136.70	4.893	19.530	5.168	16.230

Sr. No	Elevation (w.r.t. MSL) [m]	1987 (Original)		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
89	136.80	4.992	20.020	5.294	16.753
90	136.90	5.091	20.510	5.414	17.288
91	137.00	5.190	21.000	5.535	17.836
92	137.10	5.309	21.520	5.661	18.396
93	137.20	5.427	22.040	5.789	18.968
94	137.30	5.546	22.560	5.913	19.553
95	137.40	5.664	23.080	6.037	20.151
96	137.50	5.783	23.600	6.158	20.760
97	137.60	5.901	24.120	6.282	21.382
98	137.70	6.020	24.660	6.408	22.017
99	137.80	6.138	25.160	6.534	22.664
100	137.90	6.256	25.670	6.659	23.324
101	138.00	6.375	26.200	6.782	23.996
102	138.10	6.525	26.800	6.905	24.680
103	138.20	6.675	27.400	7.028	25.377
104	138.30	6.825	28.000	7.156	26.086
105	138.40	6.975	28.600	7.292	26.808
106	138.50	7.125	29.200	7.427	27.544
107	138.60	7.275	29.800	7.565	28.294
108	138.70	7.425	30.400	7.720	29.058
109	138.80	7.575	31.000	7.880	29.838
110	138.90	7.725	31.600	8.033	30.634
111	139.00	7.875	32.200	8.180	31.444
112	139.10	8.029	32.800	8.328	32.270
113	139.20	8.193	33.400	8.480	33.110
114	139.30	8.357	34.000	8.626	33.965
115	139.40	8.491	35.066	8.775	34.835
116	139.50	8.646	35.780	8.923	35.720
117	139.60	8.800	36.500	9.073	36.620
118	139.70	9.006	37.387	9.222	37.535
119	139.80	9.212	38.275	9.374	38.464
120	139.90	9.419	39.162	9.528	39.410

Sr. No	Elevation (w.r.t. MSL) [m]	1987 (Original)		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
121	140.00	9.625	40.050	9.691	40.371
122	140.10	9.788	41.145	9.860	41.348
123	140.20	9.950	42.240	10.028	42.342
124	140.30	10.113	43.335	10.190	43.353
125	140.40	10.245	44.430	10.355	44.381
126	140.50	10.438	45.525	10.525	45.425
127	140.60	10.600	46.620	10.704	46.486
128	140.70	10.763	47.715	10.888	47.566
129	140.80	10.925	48.810	11.077	48.664
130	140.90	11.088	49.905	11.270	49.781
131	141.00	11.250	51.000	11.467	50.918
132	141.10	11.450	52.300	11.668	52.075
133	141.20	11.650	53.600	11.883	53.252
134	141.30	11.850	54.900	12.129	54.453
135	141.40	12.050	56.200	12.363	55.678
136	141.50	12.250	57.500	12.646	56.928
137	141.60	12.450	58.800	12.913	58.206
138	141.70	12.650	60.100	13.185	59.511
139	141.80	12.850	61.400	13.444	60.842
140	141.90	13.050	62.700	13.710	62.200
141	142.00	13.250	64.000	13.971	63.584
142	142.10	13.435	65.300	14.245	64.995
143	142.20	13.620	66.600	14.491	66.431
144	142.30	13.805	67.900	14.729	67.892
145	142.40	13.990	69.200	14.959	69.377
146	142.50	14.175	70.500	15.167	70.883
147	142.60	14.360	71.800	15.371	72.410
148	142.70	14.545	73.100	15.564	73.957
149	142.80	14.730	74.400	15.754	75.523
150	142.90	14.905	75.700	15.938	77.107
151	143.00	15.100	77.000	16.112	78.710
152	143.10	15.310	78.600	16.275	80.329

Sr. No	Elevation (w.r.t. MSL) [m]	1987 (Original)		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
153	143.20	15.520	80.200	16.433	81.964
154	143.30	15.730	81.800	16.588	83.616
155	143.40	15.940	83.400	16.747	85.282
156	143.50	16.150	85.000	16.906	86.965
157	143.60	16.360	86.600	17.073	88.664
158	143.70	16.570	88.200	17.228	90.379
159	143.80	16.780	89.800	17.383	92.110
160	143.90	16.990	91.400	17.535	93.855
161	144.00	17.200	93.000	17.690	95.617
162	144.10	17.442	94.715	17.842	97.393
163	144.20	17.685	96.430	18.000	99.185
164	144.30	17.927	98.145	18.160	100.993
165	144.40	18.170	99.860	18.325	102.818
166	144.50	18.412	101.575	18.484	104.658
167	144.60	18.655	103.290	18.642	106.514
168	144.70	18.897	105.005	18.809	108.387
169	144.80	19.140	106.720	18.971	110.276
170	144.90	19.383	108.435	19.132	112.181
171	145.00	19.625	110.150	19.298	114.102
172	145.10	19.878	112.135	19.466	116.041
173	145.20	20.130	114.120	19.621	117.995
174	145.30	20.383	116.705	19.777	119.965
175	145.40	20.655	118.090	19.932	121.950
176	145.50	20.888	120.075	20.089	123.951
177	145.60	21.140	122.060	20.251	125.968
178	145.70	21.393	124.045	20.421	128.002
179	145.80	21.645	126.030	20.588	130.053
180	145.90	21.828	128.015	20.753	132.120
181	146.00	22.150	130.000	20.926	134.203
182	146.10	22.390	132.250	21.099	136.305
183	146.20	22.630	134.500	21.277	138.423
184	146.30	22.870	136.750	21.456	140.560

Sr. No	Elevation (w.r.t. MSL) [m]	1987 (Original)		2021 Survey	
		Area [km^2]	Gross Capacity [Mm^3]	Area [km^2]	Gross Capacity [Mm^3]
185	146.40	23.110	139.000	21.633	142.715
186	146.50	23.350	141.250	21.804	144.886
187	146.60	23.590	143.500	21.978	147.076
188	146.70	23.830	145.750	22.155	149.282
189	146.80	24.070	148.000	22.340	151.507
190	146.90	24.310	150.250	22.534	153.751
191	147.00	24.550	152.500	22.719	156.013
192	147.10	24.845	155.000	22.901	158.294
193	147.20	25.140	157.500	23.079	160.593
194	147.30	25.435	160.000	23.255	162.910
195	147.40	25.733	162.500	23.423	165.244
196	147.50	26.100	165.000	23.594	167.595
197	147.60	26.313	168.368	23.764	169.963
198	147.70	26.525	171.735	23.943	172.348
199	147.80	26.738	175.102	24.130	174.752
200	147.82	26.950	178.470	24.168	175.236

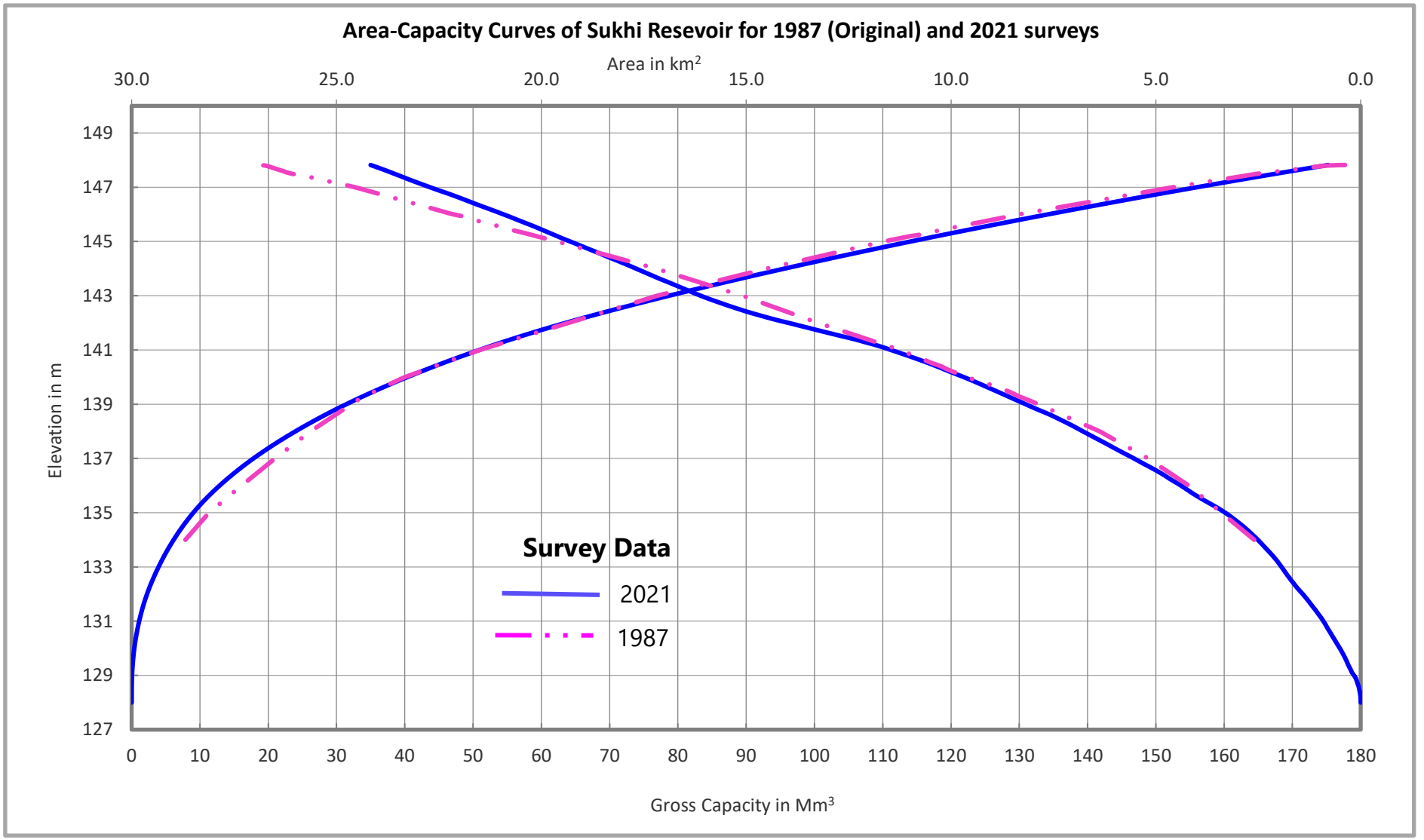


Figure 5.6: Comparison of Elevation Area capacity curves of Sukhi Reservoir for 1987(Original) and 2021 surveys

In addition to the above comparison, the live storage capacity for 2021 survey results was compared with the live storage capacity of the 2012-2013 and 1987 (Original) survey results and presented in Table 5.3 and its comparison graph is placed as Figure 5.7.

Table 5.3: Comparison of Live Storage Capacity details of 1987 (Original), 2012-2013 and 2021 survey data

Sr. No.	Elevation [m] wrt MSL	Year - 1987 (Original)		Year - 2012-2013		Year - 2021	
		Area [km^2]	Live Capacity [Mm^3]	Area [km^2]	Live Capacity [Mm^3]	Area [km^2]	Live Capacity [Mm^3]
1	135.00	3.400	0.000	3.00	0.000	3.308	0.000
2	135.10	3.480	0.477	-	-	3.412	0.336
3	135.20	3.560	0.954	-	-	3.520	0.683
4	135.30	3.640	1.431	-	-	3.636	1.040
5	135.40	3.720	1.908	-	-	3.756	1.410
6	135.50	3.800	2.385	-	-	3.870	1.791
7	135.60	3.880	2.862	-	-	3.983	2.184
8	135.70	3.960	3.339	-	-	4.090	2.587
9	135.80	4.040	3.816	-	-	4.190	3.001
10	135.90	4.120	4.293	-	-	4.287	3.425
11	136.00	4.200	4.770	4.16	3.563	4.389	3.859
12	136.10	4.299	5.260	-	-	4.496	4.303
13	136.20	4.398	5.750	-	-	4.608	4.758
14	136.30	4.497	6.240	-	-	4.714	5.225
15	136.40	4.596	6.730	-	-	4.816	5.701
16	136.50	4.695	7.220	-	-	4.927	6.188
17	136.60	4.794	7.710	-	-	5.045	6.687
18	136.70	4.893	8.200	-	-	5.168	7.197
19	136.80	4.992	8.690	-	-	5.294	7.721
20	136.90	5.091	9.180	-	-	5.414	8.256
21	137.00	5.190	9.670	5.41	8.333	5.535	8.803
22	137.10	5.309	10.190	-	-	5.661	9.363
23	137.20	5.427	10.710	-	-	5.789	9.936
24	137.30	5.546	11.230	-	-	5.913	10.521
25	137.40	5.664	11.750	-	-	6.037	11.118
26	137.50	5.783	12.270	-	-	6.158	11.728
27	137.60	5.901	12.790	-	-	6.282	12.350
28	137.70	6.020	13.330	-	-	6.408	12.984
29	137.80	6.138	13.830	-	-	6.534	13.632
30	137.90	6.256	14.340	-	-	6.659	14.291
31	138.00	6.375	14.870	6.76	14.406	6.782	14.963
32	138.10	6.525	15.470	-	-	6.905	15.648
33	138.20	6.675	16.070	-	-	7.028	16.344
34	138.30	6.825	16.670	-	-	7.156	17.053

Sr. No.	Elevation [m] wrt MSL	Year - 1987 (Original)		Year - 2012-2013		Year - 2021	
		Area [km^2]	Live Capacity [Mm^3]	Area [km^2]	Live Capacity [Mm^3]	Area [km^2]	Live Capacity [Mm^3]
35	138.40	6.975	17.270	-	-	7.292	17.776
36	138.50	7.125	17.870	-	-	7.427	18.512
37	138.60	7.275	18.470	-	-	7.565	19.261
38	138.70	7.425	19.070	-	-	7.720	20.026
39	138.80	7.575	19.670	-	-	7.880	20.806
40	138.90	7.725	20.270	-	-	8.033	21.601
41	139.00	7.875	20.870	8.21	21.877	8.180	22.412
42	139.10	8.029	21.470	-	-	8.328	23.237
43	139.20	8.193	22.070	-	-	8.480	24.078
44	139.30	8.357	22.670	-	-	8.626	24.933
45	139.40	8.491	23.736	-	-	8.775	25.803
46	139.50	8.646	24.450	-	-	8.923	26.688
47	139.60	8.800	25.170	-	-	9.073	27.588
48	139.70	9.006	26.057	-	-	9.222	28.502
49	139.80	9.212	26.945	-	-	9.374	29.432
50	139.90	9.419	27.832	-	-	9.528	30.377
51	140.00	9.625	28.720	9.75	30.841	9.691	31.338
52	140.10	9.788	29.815	-	-	9.860	32.316
53	140.20	9.950	30.910	-	-	10.028	33.310
54	140.30	10.113	32.005	-	-	10.190	34.321
55	140.40	10.245	33.100	-	-	10.355	35.348
56	140.50	10.438	34.195	-	-	10.525	36.392
57	140.60	10.600	35.290	-	-	10.704	37.454
58	140.70	10.763	36.385	-	-	10.888	38.533
59	140.80	10.925	37.480	-	-	11.077	39.631
60	140.90	11.088	38.575	-	-	11.270	40.749
61	141.00	11.250	39.670	11.38	41.394	11.467	41.886
62	141.10	11.450	40.970	-	-	11.668	43.042
63	141.20	11.650	42.270	-	-	11.883	44.220
64	141.30	11.850	43.570	-	-	12.129	45.421
65	141.40	12.050	44.870	-	-	12.363	46.645
66	141.50	12.250	46.170	-	-	12.646	47.896
67	141.60	12.450	47.470	-	-	12.913	49.174
68	141.70	12.650	48.770	-	-	13.185	50.478
69	141.80	12.850	50.070	-	-	13.444	51.810
70	141.90	13.050	51.370	-	-	13.710	53.167
71	142.00	13.250	52.670	13.11	53.631	13.971	54.552
72	142.10	13.435	53.970	-	-	14.245	55.962
73	142.20	13.620	55.270	-	-	14.491	57.399

Sr. No.	Elevation [m] wrt MSL	Year - 1987 (Original)		Year - 2012-2013		Year - 2021	
		Area [km^2]	Live Capacity [Mm^3]	Area [km^2]	Live Capacity [Mm^3]	Area [km^2]	Live Capacity [Mm^3]
74	142.30	13.805	56.570	-	-	14.729	58.860
75	142.40	13.990	57.870	-	-	14.959	60.344
76	142.50	14.175	59.170	-	-	15.167	61.851
77	142.60	14.360	60.470	-	-	15.371	63.378
78	142.70	14.545	61.770	-	-	15.564	64.924
79	142.80	14.730	63.070	-	-	15.754	66.490
80	142.90	14.905	64.370	14.94	67.648	15.938	68.075
81	143.00	15.100	65.670			16.112	69.677
82	143.10	15.310	67.270	-	-	16.275	71.297
83	143.20	15.520	68.870	-	-	16.433	72.932
84	143.30	15.730	70.470	-	-	16.588	74.583
85	143.40	15.940	72.070	-	-	16.747	76.250
86	143.50	16.150	73.670	-	-	16.906	77.932
87	143.60	16.360	75.270	-	-	17.073	79.631
88	143.70	16.570	76.870	-	-	17.228	81.347
89	143.80	16.780	78.470	-	-	17.383	83.077
90	143.90	16.990	80.070	-	-	17.535	84.823
91	144.00	17.200	81.670	16.86	83.540	17.690	86.584
92	144.10	17.442	83.385	-	-	17.842	88.361
93	144.20	17.685	85.100	-	-	18.000	90.153
94	144.30	17.927	86.815	-	-	18.160	91.961
95	144.40	18.170	88.530	-	-	18.325	93.785
96	144.50	18.412	90.245	-	-	18.484	95.626
97	144.60	18.655	91.960	-	-	18.642	97.482
98	144.70	18.897	93.675	-	-	18.809	99.354
99	144.80	19.140	95.390	-	-	18.971	101.243
100	144.90	19.383	97.105	-	-	19.132	103.149
101	145.00	19.625	98.820	18.88	101.402	19.298	105.070
102	145.10	19.878	100.805	-	-	19.466	107.008
103	145.20	20.130	102.790	-	-	19.621	108.963
104	145.30	20.383	105.375	-	-	19.777	110.932
105	145.40	20.655	106.760	-	-	19.932	112.918
106	145.50	20.888	108.745	-	-	20.089	114.919
107	145.60	21.140	110.730	-	-	20.251	116.936
108	145.70	21.393	112.715	-	-	20.421	118.970
109	145.80	21.645	114.700	-	-	20.588	121.020
110	145.90	21.828	116.685	-	-	20.753	123.087
111	146.00	22.150	118.670	21.00	121.331	20.926	125.171
112	146.10	22.390	120.920	-	-	21.099	127.272

Sr. No.	Elevation [m] wrt MSL	Year - 1987 (Original)		Year - 2012-2013		Year - 2021	
		Area [km^2]	Live Capacity [Mm^3]	Area [km^2]	Live Capacity [Mm^3]	Area [km^2]	Live Capacity [Mm^3]
113	146.20	22.630	123.170	-	-	21.277	129.391
114	146.30	22.870	125.420	-	-	21.456	131.528
115	146.40	23.110	127.670	-	-	21.633	133.682
116	146.50	23.350	129.920	-	-	21.804	135.854
117	146.60	23.590	132.170	-	-	21.978	138.043
118	146.70	23.830	134.420	-	-	22.155	140.250
119	146.80	24.070	136.670	-	-	22.340	142.475
120	146.90	24.310	138.920	-	-	22.534	144.718
121	147.00	24.550	141.170	23.21	143.422	22.719	146.981
122	147.10	24.845	143.670	-	-	22.901	149.262
123	147.20	25.140	146.170	-	-	23.079	151.561
124	147.30	25.435	148.670	-	-	23.255	153.878
125	147.40	25.733	151.170	-	-	23.423	156.212
126	147.50	26.100	153.670	-	-	23.594	158.562
127	147.60	26.313	157.038	-	-	23.764	160.930
128	147.70	26.525	160.405	-	-	23.943	163.316
129	147.80	26.738	163.772	-	-	24.130	165.719
130	147.82	26.950	167.140	25.09	163.218	24.168	166.204

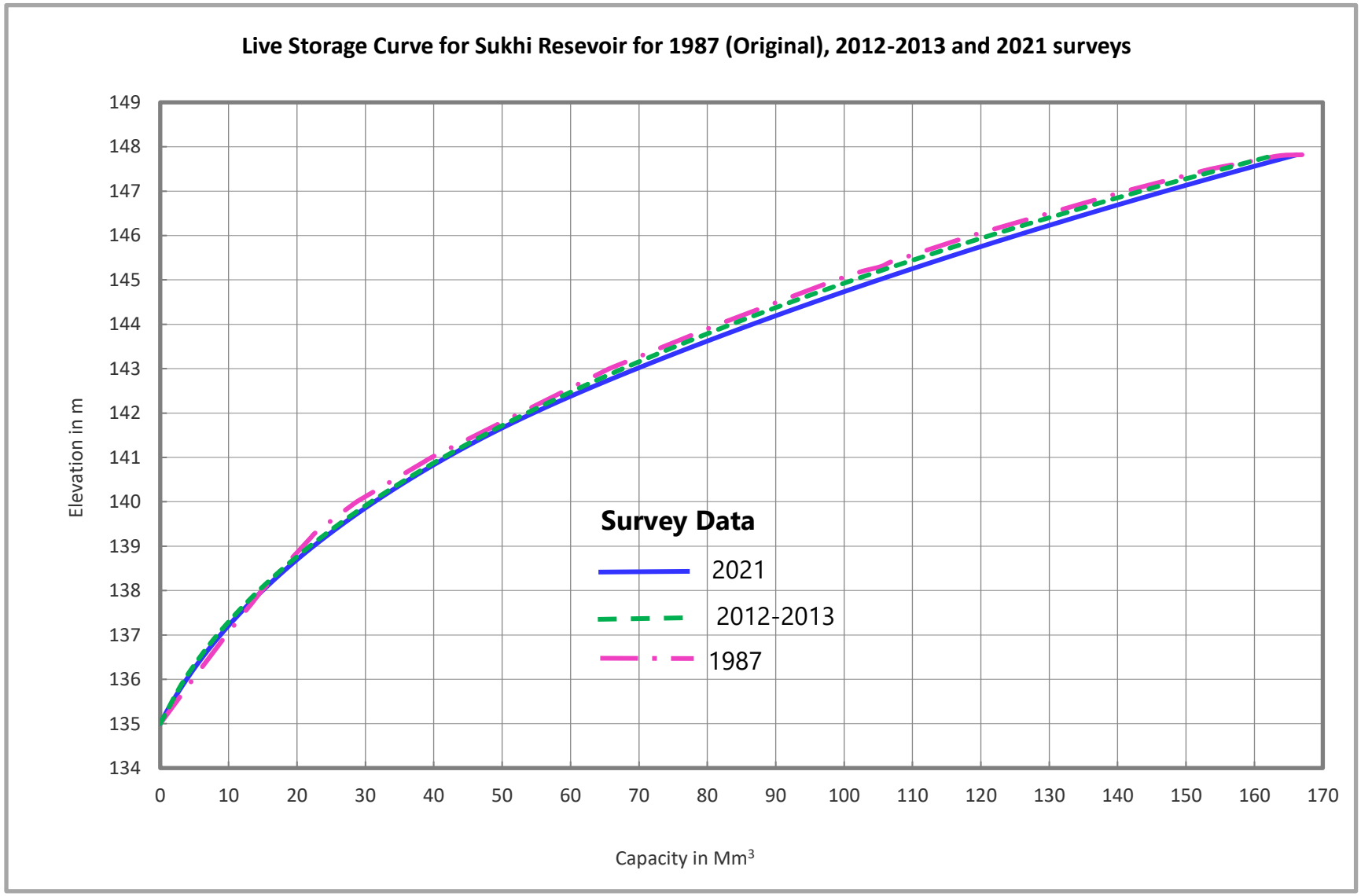


Figure 5.7: Comparison of Live capacity curves of Sukhi Reservoir for 1987(Original), 2012-2013 and 2021 surveys

5.4 Sedimentation in Reservoir

The present survey of Sukhi reservoir was carried out between April -May 2021 and June – July 2021. Original project data is for the year 1987. The catchment area considered for sedimentation studies is 411.81 km^2. In the present study, the age of the reservoir is considered as 34 years (1987 – 2021). As per 2021 survey, the total area of reservoir at FRL 147.82 m is 24.168 km^2 and the corresponding gross storage capacity is 175.236 Mm^3. Table 5.4 details the gross capacity loss, rate of sedimentation and annual % loss in gross storage capacity w.r.t. original project capacity (1987).

Table 5.4: Sedimentation in Sukhi Reservoir based on 1987 (Original) and 2021 survey data

Year	1987	2021
Storage Capacity in Mm^3		
Dead	11.330	9.032
Live	167.140	166.204
Gross	178.470	175.236
Loss of Storage Capacity in Mm^3		(w.r.t. 1987)
Dead	NA	2.298
Live	NA	0.936
Gross	NA	3.234
Sedimentation Rate in Ham/100 km^2/Year		(w.r.t. 1987)
Dead	NA	1.641
Live	NA	0.668
Gross	-	2.310
Annual % loss		(w.r.t. 1987)
Dead	-	0.038
Live	-	0.015
Gross	-	0.053
Class of reservoir as per IS -12182 (1987)	As per design	Insignificant
Volume of sediment (w.r.t. 1987) deposited on bed in 2021= Loss of storage capacity= 3.234 Mm^3		
Note: Sign Convention: -ve sign shows desiltation and +ve sign shows siltation		

Table 5.5 gives the results of the Trap efficiency and Sedimentation Index calculated for Sukhi reservoir as per the methodology given in IS 12182-1987.

Table 5.5: Trap Efficiency and Sedimentation Index for Sukhi Reservoir

Trap Efficiency	Sedimentation Index
97%	6.938 x 10^{10} sec^2/m

In Table 5.4, the Project data of 1987 has been compared with 2021 survey results to understand the sedimentation in Sukhi reservoir. It may be observed that there is a reduction in the storage capacity of the reservoir due to siltation.

Table 5.6: Sedimentation Volumes from Surveys of Previous Years of 1987 and 2021 (Gross Storage Capacity)

Sr. No.	Year of Survey	Source of Data	Period (years)	Reservoir Capacity (Mm^3)	Loss of Gross Capacity Since 1987 survey			Observed Rate of Sedimentation Since 1987 survey (Ha m / 100 Sq km/Yr)
				Gross	[Mm^3]	% Cumulative	Remark	
1	1987 (Original)	Govt.	-	178.470	-	-	-	-
2	2021	Present survey	34	175.236	3.234	1.812	Siltation	2.310

- As per 2021 survey results, the volume of sediment deposited or the loss in gross storage capacity w.r.t. 1987 Project data is 3.234 Mm^3.
- The rate of siltation in Sukhi reservoir is 0.095 Mm^3/year.
- The average rate of siltation in the Sukhi reservoir during the 34 years life span (1987 – 2021), works out to 2.310 Ha m/100 sq km/year.
- The annual % loss in Sukhi reservoir during the 34 years life span is 0.053 % and hence, the reservoir is classified as "Insignificant" category as per IS 12182 (1987).
- Trap Efficiency and sedimentation Index calculated for Sukhi reservoir as per methodology give in IS 12182-1987 is 97% and 6.938 x 10^{10} sec^2/m respectively.

Previous survey, which was based on remote sensing technique, was carried out in the year 2012-2013 and is between MDDL to FRL. Hence, the live storage capacity of 1987, 2012-2013 and 2021 was compared. Table 5.7 and 5.8 gives the comparison results.

Table 5.7: Sedimentation in Sukhi Reservoir based on 1987 (Original), 2013, and 2021 survey data

Year	1987	2013	2021	2021
Live Storage Capacity in Mm^3				
Live	167.140	163.218	166.204	166.204
Loss of Live Storage Capacity in Mm^3		(w.r.t. 1987)	(w.r.t. 2013)	(w.r.t. 1987)
Live		3.922	-2.986	0.936
Sedimentation Rate in Ham/100 km^2/Year		(w.r.t. 1987)	(w.r.t. 2013)	(w.r.t. 1987)
Live		3.663	-9.064	0.668
Annual % loss		(w.r.t. 1987)	(w.r.t. 2013)	(w.r.t. 1987)
Live		0.090	-0.229	0.016
Remarks		Siltation	Desiltation	Siltation

Notes:
1. Sign Convention: -ve sign shows desiltation and +ve sign shows siltation
2. Since 2013 survey results is based on remote sensing technique, live capacity was only considered for comparison study

Table 5.8: Sedimentation Volumes from Surveys of Previous Years of 1987, 2013 and 2021 (Live Storage Capacity)

Sr. No.	Year of Survey	Source of Data	Period (years)	Reservoir Capacity (Mm^3)	Loss of Live Capacity (Since 1987 survey)			Observed Rate of Sedimentation Since 1987 survey (Ha m / 100 Sq km/Yr)
				Live	[Mm^3]	% Cumulative	Remark	
1	1987 (Original)	Govt.	-	167.140	-	-	-	-
2	2012-2013	Govt.	26	163.218	3.922	2.35	Siltation	3.663
3	2021	Present survey	34	166.204	0.936	0.56	Desiltation	0.668

In comparison with 2012-2013 survey, the present survey results indicate desiltation process in the reservoir. However, w.r.t. original project data (1987), 2021 survey results indicate loss in live storage capacity. The reason behind the present survey results showing siltation w.r.t. 1987 Original capacity could be due to change of upstream catchment characteristics. Also, there could be some anthropogenic activities in the catchment area which might result in siltation in the reservoir.

Table 5.9 gives the gross, live and dead storage capacity from bed level to FRL at 0.1 m interval.

Table 5.9: Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Sukhi reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
1	128.00	0.00000	--	0.00000	**Bed level**
2	128.10	0.00004	--	0.00004	--
3	128.20	0.00022	--	0.00022	--
4	128.30	0.001	--	0.001	--
5	128.40	0.003	--	0.003	--
6	128.50	0.006	--	0.006	--
7	128.60	0.010	--	0.010	--
8	128.70	0.016	--	0.016	--
9	128.80	0.025	--	0.025	--
10	128.90	0.036	--	0.036	--
11	129.00	0.050	--	0.050	--
12	129.10	0.069	--	0.069	--
13	129.20	0.092	--	0.092	--
14	129.30	0.117	--	0.117	--
15	129.40	0.147	--	0.147	--
16	129.50	0.179	--	0.179	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Sukhi reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
17	129.60	0.214	--	0.214	--
18	129.70	0.252	--	0.252	--
19	129.80	0.294	--	0.294	--
20	129.90	0.339	--	0.339	--
21	130.00	0.388	--	0.388	--
22	130.10	0.441	--	0.441	--
23	130.20	0.498	--	0.498	--
24	130.30	0.560	--	0.560	--
25	130.40	0.625	--	0.625	--
26	130.50	0.694	--	0.694	--
27	130.60	0.767	--	0.767	--
28	130.70	0.844	--	0.844	--
29	130.80	0.926	--	0.926	--
30	130.90	1.011	--	1.011	--
31	131.00	1.100	--	1.100	--
32	131.10	1.193	--	1.193	--
33	131.20	1.291	--	1.291	--
34	131.30	1.393	--	1.393	--
35	131.40	1.501	--	1.501	--
36	131.50	1.613	--	1.613	--
37	131.60	1.731	--	1.731	--
38	131.70	1.854	--	1.854	--
39	131.80	1.982	--	1.982	--
40	131.90	2.115	--	2.115	--
41	132.00	2.254	--	2.254	--
42	132.10	2.398	--	2.398	--
43	132.20	2.549	--	2.549	--
44	132.30	2.705	--	2.705	--
45	132.40	2.866	--	2.866	--
46	132.50	3.033	--	3.033	--
47	132.60	3.205	--	3.205	--
48	132.70	3.381	--	3.381	--
49	132.80	3.563	--	3.563	--
50	132.90	3.749	--	3.749	--
51	133.00	3.940	--	3.940	--
52	133.10	4.136	--	4.136	--
53	133.20	4.337	--	4.337	--
54	133.30	4.542	--	4.542	--
55	133.40	4.754	--	4.754	--
56	133.50	4.971	--	4.971	--
57	133.60	5.194	--	5.194	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Sukhi reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
58	133.70	5.423	--	5.423	--
59	133.80	5.658	--	5.658	--
60	133.90	5.900	--	5.900	--
61	134.00	6.148	--	6.148	--
62	134.10	6.402	--	6.402	--
63	134.20	6.664	--	6.664	--
64	134.30	6.932	--	6.932	--
65	134.40	7.208	--	7.208	--
66	134.50	7.491	--	7.491	--
67	134.60	7.782	--	7.782	--
68	134.70	8.082	--	8.082	--
69	134.80	8.390	--	8.390	--
70	134.90	8.706	--	8.706	--
71	135.00	9.032	--	9.032	**MDDL**
72	135.10	9.368	0.336	9.032	--
73	135.20	9.715	0.683	9.032	--
74	135.30	10.073	1.040	9.032	--
75	135.40	10.442	1.410	9.032	--
76	135.50	10.824	1.791	9.032	--
77	135.60	11.216	2.184	9.032	--
78	135.70	11.620	2.587	9.032	--
79	135.80	12.034	3.001	9.032	--
80	135.90	12.458	3.425	9.032	--
81	136.00	12.891	3.859	9.032	--
82	136.10	13.336	4.303	9.032	--
83	136.20	13.791	4.758	9.032	--
84	136.30	14.257	5.225	9.032	--
85	136.40	14.733	5.701	9.032	--
86	136.50	15.221	6.188	9.032	--
87	136.60	15.719	6.687	9.032	--
88	136.70	16.230	7.197	9.032	--
89	136.80	16.753	7.721	9.032	--
90	136.90	17.288	8.256	9.032	--
91	137.00	17.836	8.803	9.032	--
92	137.10	18.396	9.363	9.032	--
93	137.20	18.968	9.936	9.032	--
94	137.30	19.553	10.521	9.032	--
95	137.40	20.151	11.118	9.032	--
96	137.50	20.760	11.728	9.032	--
97	137.60	21.382	12.350	9.032	--
98	137.70	22.017	12.984	9.032	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Sukhi reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
99	137.80	22.664	13.632	9.032	--
100	137.90	23.324	14.291	9.032	--
101	138.00	23.996	14.963	9.032	--
102	138.10	24.680	15.648	9.032	--
103	138.20	25.377	16.344	9.032	--
104	138.30	26.086	17.053	9.032	--
105	138.40	26.808	17.776	9.032	--
106	138.50	27.544	18.512	9.032	--
107	138.60	28.294	19.261	9.032	--
108	138.70	29.058	20.026	9.032	--
109	138.80	29.838	20.806	9.032	--
110	138.90	30.634	21.601	9.032	--
111	139.00	31.444	22.412	9.032	--
112	139.10	32.270	23.237	9.032	--
113	139.20	33.110	24.078	9.032	--
114	139.30	33.965	24.933	9.032	--
115	139.40	34.835	25.803	9.032	--
116	139.50	35.720	26.688	9.032	--
117	139.60	36.620	27.588	9.032	--
118	139.70	37.535	28.502	9.032	--
119	139.80	38.464	29.432	9.032	--
120	139.90	39.410	30.377	9.032	--
121	140.00	40.371	31.338	9.032	--
122	140.10	41.348	32.316	9.032	--
123	140.20	42.342	33.310	9.032	--
124	140.30	43.353	34.321	9.032	--
125	140.40	44.381	35.348	9.032	--
126	140.50	45.425	36.392	9.032	--
127	140.60	46.486	37.454	9.032	--
128	140.70	47.566	38.533	9.032	--
129	140.80	48.664	39.631	9.032	--
130	140.90	49.781	40.749	9.032	--
131	141.00	50.918	41.886	9.032	--
132	141.10	52.075	43.042	9.032	--
133	141.20	53.252	44.220	9.032	--
134	141.30	54.453	45.421	9.032	--
135	141.40	55.678	46.645	9.032	--
136	141.50	56.928	47.896	9.032	--
137	141.60	58.206	49.174	9.032	--
138	141.70	59.511	50.478	9.032	--
139	141.80	60.842	51.810	9.032	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Sukhi reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
140	141.90	62.200	53.167	9.032	--
141	142.00	63.584	54.552	9.032	--
142	142.10	64.995	55.962	9.032	--
143	142.20	66.431	57.399	9.032	--
144	142.30	67.892	58.860	9.032	--
145	142.40	69.377	60.344	9.032	--
146	142.50	70.883	61.851	9.032	--
147	142.60	72.410	63.378	9.032	--
148	142.70	73.957	64.924	9.032	--
149	142.80	75.523	66.490	9.032	--
150	142.90	77.107	68.075	9.032	--
151	143.00	78.710	69.677	9.032	--
152	143.10	80.329	71.297	9.032	--
153	143.20	81.964	72.932	9.032	--
154	143.30	83.616	74.583	9.032	--
155	143.40	85.282	76.250	9.032	--
156	143.50	86.965	77.932	9.032	--
157	143.60	88.664	79.631	9.032	--
158	143.70	90.379	81.347	9.032	--
159	143.80	92.110	83.077	9.032	--
160	143.90	93.855	84.823	9.032	--
161	144.00	95.617	86.584	9.032	--
162	144.10	97.393	88.361	9.032	--
163	144.20	99.185	90.153	9.032	--
164	144.30	100.993	91.961	9.032	--
165	144.40	102.818	93.785	9.032	--
166	144.50	104.658	95.626	9.032	--
167	144.60	106.514	97.482	9.032	--
168	144.70	108.387	99.354	9.032	--
169	144.80	110.276	101.243	9.032	--
170	144.90	112.181	103.149	9.032	--
171	145.00	114.102	105.070	9.032	--
172	145.10	116.041	107.008	9.032	--
173	145.20	117.995	108.963	9.032	--
174	145.30	119.965	110.932	9.032	--
175	145.40	121.950	112.918	9.032	--
176	145.50	123.951	114.919	9.032	--
177	145.60	125.968	116.936	9.032	--
178	145.70	128.002	118.970	9.032	--
179	145.80	130.053	121.020	9.032	--
180	145.90	132.120	123.087	9.032	--

Gross, Live and Dead storage capacity from bed level to FRL at 0.1 m interval - Sukhi reservoir					
Sr. No.	Elevation [m]	Gross Capacity [Mm^3]	Live Capacity [Mm^3]	Dead Capacity [Mm^3]	Remarks
181	146.00	134.203	125.171	9.032	--
182	146.10	136.305	127.272	9.032	--
183	146.20	138.423	129.391	9.032	--
184	146.30	140.560	131.528	9.032	--
185	146.40	142.715	133.682	9.032	--
186	146.50	144.886	135.854	9.032	--
187	146.60	147.076	138.043	9.032	--
188	146.70	149.282	140.250	9.032	--
189	146.80	151.507	142.475	9.032	--
190	146.90	153.751	144.718	9.032	--
191	147.00	156.013	146.981	9.032	--
192	147.10	158.294	149.262	9.032	--
193	147.20	160.593	151.561	9.032	--
194	147.30	162.910	153.878	9.032	--
195	147.40	165.244	156.212	9.032	--
196	147.50	167.595	158.562	9.032	--
197	147.60	169.963	160.930	9.032	--
198	147.70	172.348	163.316	9.032	--
199	147.80	174.752	165.719	9.032	--
200	147.82	175.236	166.204	9.032	FRL

Following table shows the summary of the results of the previous hydrography survey carried out in the Sukhi reservoir.

Table 5.10: Summary of previous survey (Live Storage Capacity)

Year of Survey	Original survey (1987)	Hydrograph survey (1997)	Hydrograph survey (1999)	Hydrograph survey (2005)	Hydrograph survey (2005)
Live capacity in Mm^3	167.14	156.08	164.24	167.213	166.204
Cumulative loss in Mm^3	--	11.06	2.9	-0.073	0.936
Cumulative loss %	--	6.62	1.74	N/A	0.56

6. Conclusions

- The reservoir topography was uneven, with reservoir bed level ranging from 128.0 m to 147.82 m w.r.t. MSL. The lowest reservoir bed level 128.0 m was found near the upstream face of the dam boundary and it becomes shallower as we go further upstream from the dam face. Also, the reservoir bed tends to get shallower as we go further in north-west, north, east and south-east directions away from the dam wall within the survey area.
- Current survey results indicate that the loss of gross storage capacity (w.r.t. 1987 project data) due to siltation in Sukhi reservoir is 3.234 Mm^3. The probable reasons for the decrease of gross storage capacity could be change in hydrodynamics due to change of upstream discharges as sediment carrying capacity of the river and its tributaries. Moreover, the cause of changes could be anthropogenic intervention towards siltation of the reservoir.
- In comparison with 1987 project data, 2021 results indicate decrease in storage capacity due to siltation. The annual % loss in gross storage capacity is 0.053 % and hence, the reservoir is classified as "Insignificant" category as per IS 12182 (1987).
- The sedimentation volumes, sedimentation rates, loss of storage capacity, trap efficiency, sedimentation index have been reported in the study. Moreover, the tables for gross, live and dead storage capacity of reservoir at every 0.1 m interval from lowest bed level to FRL have been provided.

7. References

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Appendix A

Diary of Events

(01 page)

Diary of Events (Bathymetry and Topography Survey)	
Date	**Events**
Bathymetry Survey	
30 March 2021	Survey personnel with survey boat 'Polaris' reached Sukhi reservoir.
31 March 2021	Polaris deployed on Sukhi reservoir
1 April 2021	Mobilization commenced.
2 April 2021	Mobilization in progress.
3 April 2021	Mobilization completed. Calibration/verification Mobilization commenced and completed. Bathymetry survey commenced.
4 April 2021 – 4 May 2021	Bathymetry Survey continued.
5 May 2021	Bathymetry Survey completed
6 May 2021	Waiting for office clearance for demob from Sukhi dam.
7 May 2021	Demobilization started.
8 May 2021	Demobilization completed.
9 May 2021	Transported equipment and Polaris to Karjan Dam Site.
Topography Survey	
24 June 2021	Topography survey team with equipment reached Sukhi Dam. Mobilisation and calibration commenced and completed.
25 June 2021	Topography survey commenced
26 -28 June 2021	Topography survey continued.
29 June - 8 July 2021	Topography survey suspended as survey team facing health issues.
9 July 2021	Topography survey resumed.
10-23 July 2021	Topography survey continued.
24 July 2021	Topography survey completed.

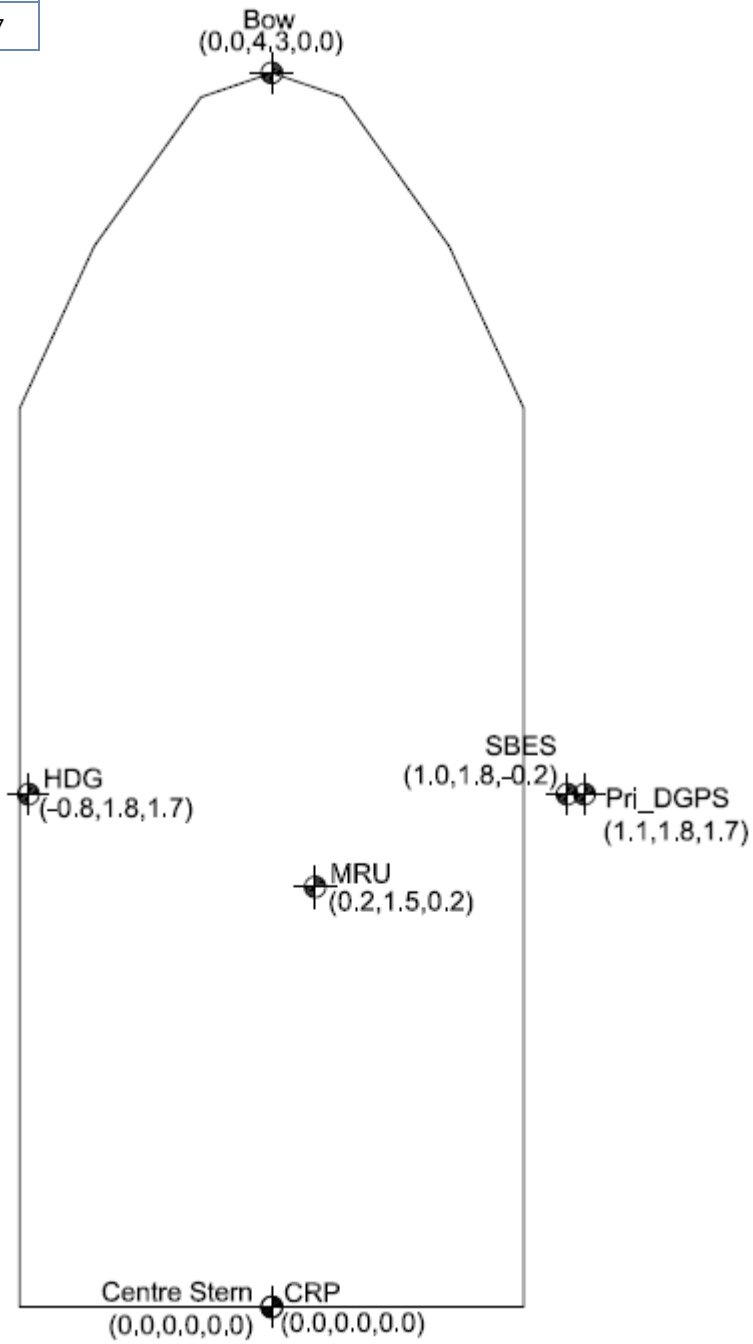
Appendix B

Survey Vessel Sensor Offsets

(01 Page)

Survey Vessel 'Polaris' Sensor Offset Diagram

Sensor Offsets: Polaris			
Starfix.Suite Name	**X [m]**	**Y [m]**	**Z [m]**
CRP	0.00	0.00	0.00
Centre Stern	0.00	0.00	0.00
Bow	0.00	4.26	0.00
Pri_DGPS	1.08	1.82	1.77
HDG	-0.84	1.82	1.77
SBES	1.02	1.77	-0.22
MRU	0.2	1.45	0.17

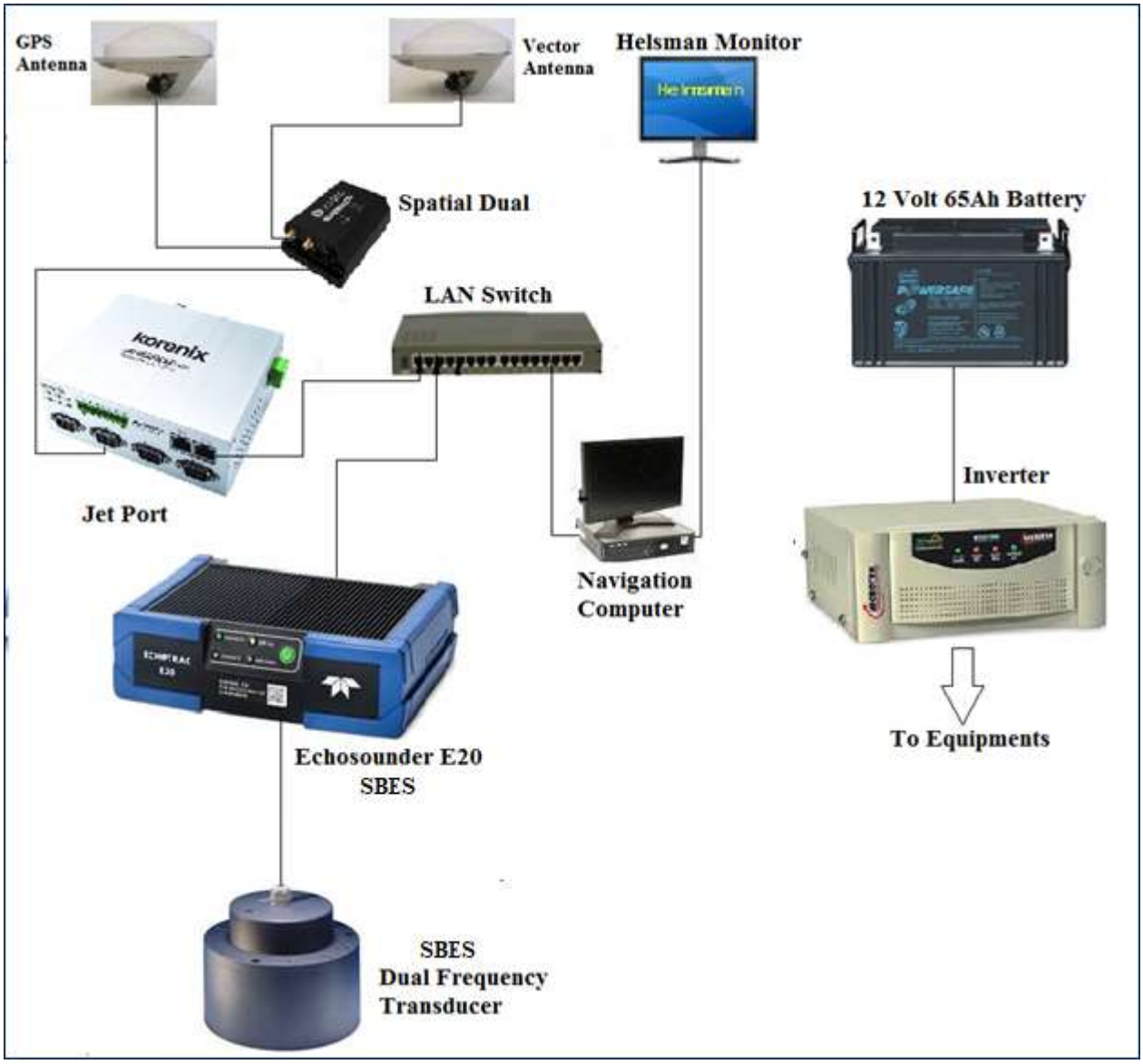


Appendix C

Equipment Layout Diagram

(01 Page)

Equipment Layout Diagram onboard Polaris



Appendix D

Results of Field Calibrations / Verifications

(18 pages)

FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of SUKHI-TBM

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	SUKHI-TBM	**Location:**	Gujarat, West Coast of India
Party Chief :	Arpit Bose	**Job Engineer/Surveyor :**	Mathiazhagan V.
Date of Observation: (Date & Time)	02-04-2021 & 11:22hrs	**End of Observation: (Date & Time)**	02-04-2021 & 11:52hrs

1. Station Name: SUKHI-TBM.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075° East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
TRIMBLE BX992 RECEIVER	025-000096 11	PRI_DGPS	Mean position report	FBF	NA	0.02

A= SUKHI-TBM Height is 153.615m

B= Antenna Height from BM 1.518m (Measured by Tape)

Ellipsoidal height of Antenna= 97.183m

Ellipsoidal Height of BM 97.183m-1.518m=95.665m

C is the center point of BM.

Position Of Antenna:-

Latitude: 22°26'19.91600"N, **Longitude:** 73°52'58.91618"E

Easting: 3,85,058.568m E **Northing:** 24,81,832.210m N

Prepared By: Arpit Bose.

BATHYMETRY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630_SUKHI DAM		
Location	GUJRAT		
Client	Govt of Gujarat	**Vessel**	Tripod
Comment			

Session Name: SUKHI-TBM-v3 Records Used: 1091 of 1800

Start Time: 02 Apr 2021, 11:22:44+05:30 End Time: 02 Apr 2021, 11:52:43+05:30 Session Length: 00:29:59

Mean Position for Tripod CentreOfGravity		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°26'19.91600"N	22°26'19.91600"N
Longitude	073°52'58.91618"E	073°52'58.91618"E
Height	97.183m Ell.	97.183m Ell.
Easting	3,85,058.568m E (SD: ±0.02m)	
Northing	24,81,832.210m N (SD: ±0.02m)	
Height	155.606m Ort. (SD: ±0.04m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

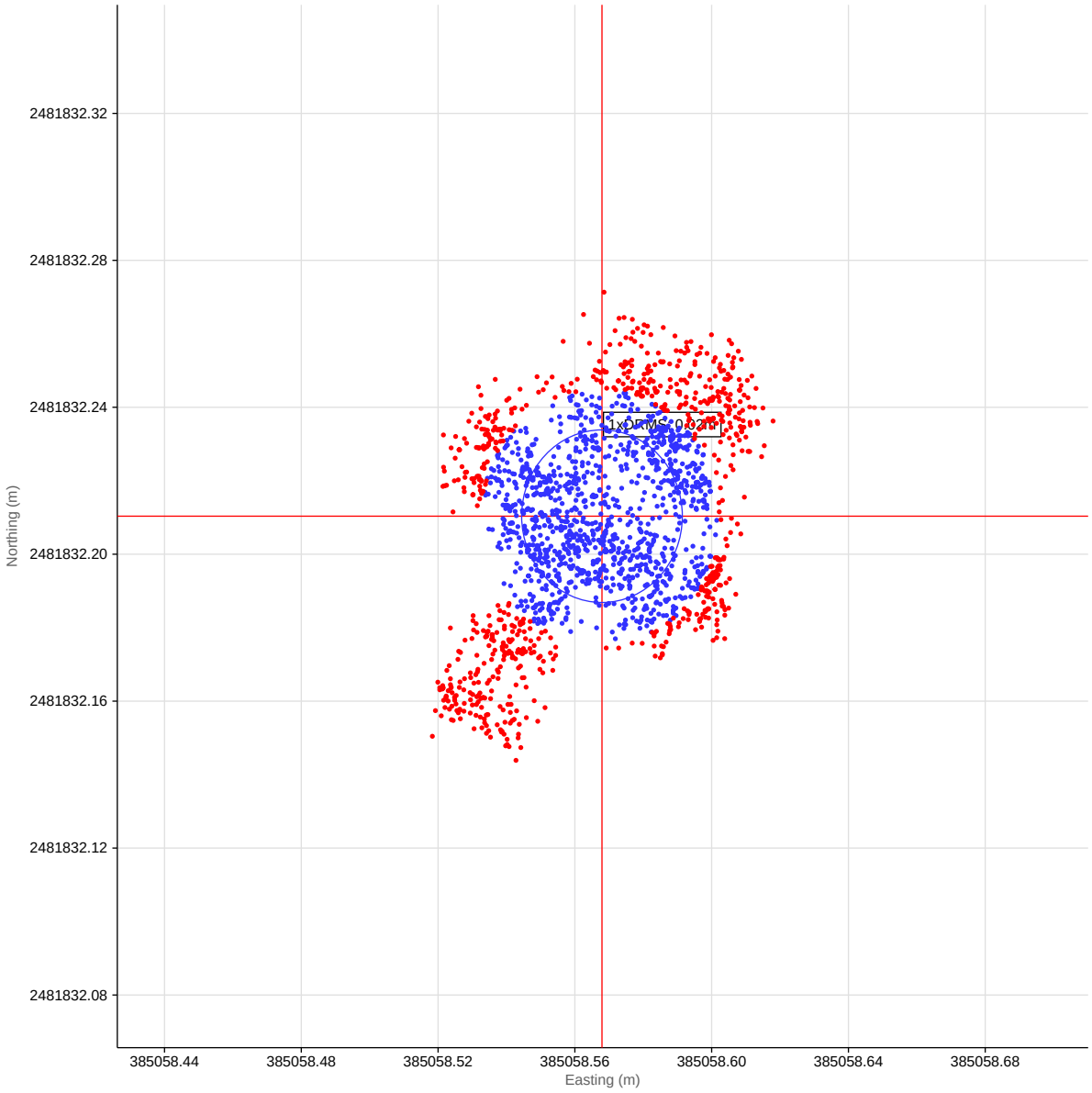
Arpit Bose
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer
SUKHI DAM
Govt. of Gujarat

Geodetic Parameters

Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

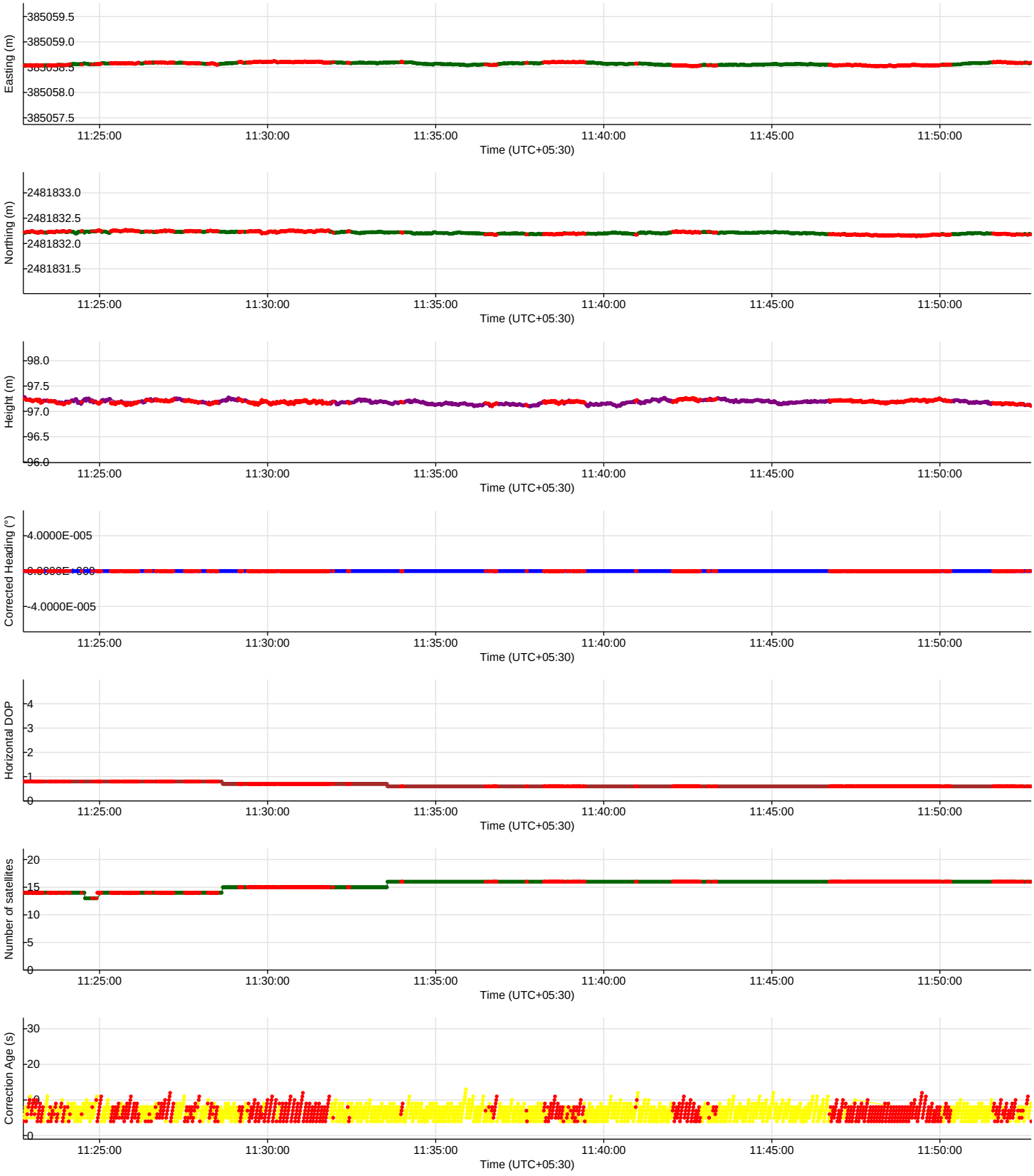
Scatter Plot



Mean Position

	Easting	Northing
Tripod	3,85,058.568m E	24,81,832.210m N

Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of SUKHI-TBM

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	SUKHI-TBM	**Location:**	Gujarat, West Coast of India
Party Chief :	Arpit Bose	**Job Engineer/Surveyor :**	Mathiazhagan V.
Date of Observation: (Date & Time)	02-04-2021 & 13:18hrs	**End of Observation: (Date & Time)**	02-04-2021 & 13:48hrs

1. Station Name: SUKHI-TBM

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075° East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
SPATIAL DUAL RECIEVER	25-272968	PRI_DGPS	Mean position report	FBF	NA	0.02

A= SUKHI-TBM Height is 153.615m

B= Antenna Height from BM 1.656m (Measured by Tape)

Ellipsoidal height of Antenna= 97.462m

Ellipsoidal Height of BM 97.462m-1.656m=95.806m

C is the center point of BM.

Position Of Antenna:-

Latitude: 22°26'19.91472"N, **Longitude:** 73°52'58.91136"E

Easting: 3,85,058.430m E **Northing:** 24,81,832.172m N

Prepared By: Arpit Bose.

BATHYMETRY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630_SUKHI DAM		
Location	GUJRAT		
Client	Govt of Gujarat	**Vessel**	Tripod
Comment			

Session Name: SUKHI-TBM_SPD-v1 Records Used: 991 of 1799

Start Time: 02 Apr 2021, 13:18:11+05:30 End Time: 02 Apr 2021, 13:48:10+05:30 Session Length: 00:29:59

Mean Position for Tripod CentreOfGravity		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°26'19.91472"N	22°26'19.91472"N
Longitude	073°52'58.91136"E	073°52'58.91136"E
Height	97.462m Ell.	97.462m Ell.
Easting	3,85,058.430m E (SD: ±0.02m)	
Northing	24,81,832.172m N (SD: ±0.01m)	
Height	155.886m Ort. (SD: ±0.05m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

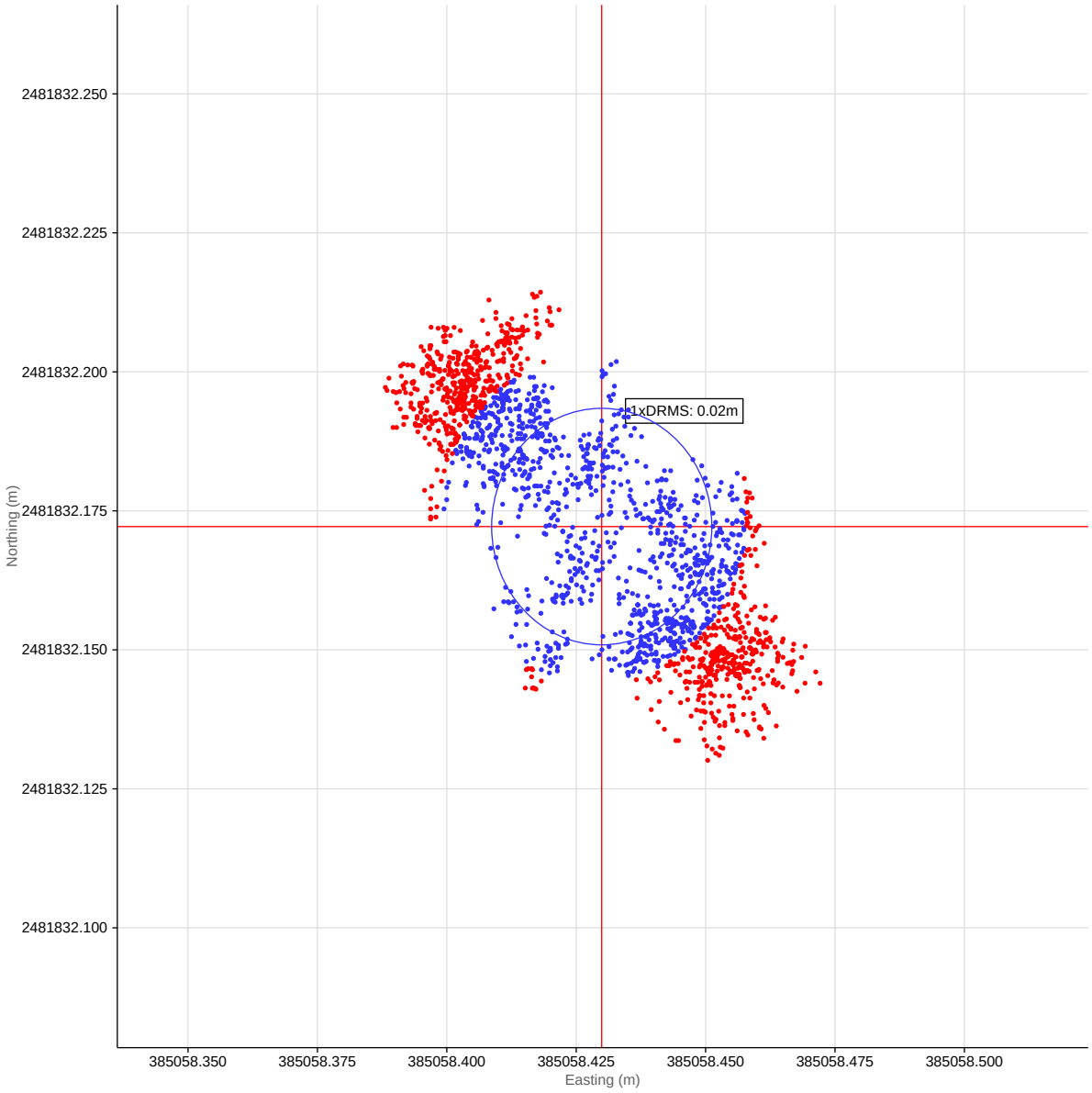
Arpit Bose
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer
SUKHI DAM
Govt. of Gujarat

Geodetic Parameters

Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

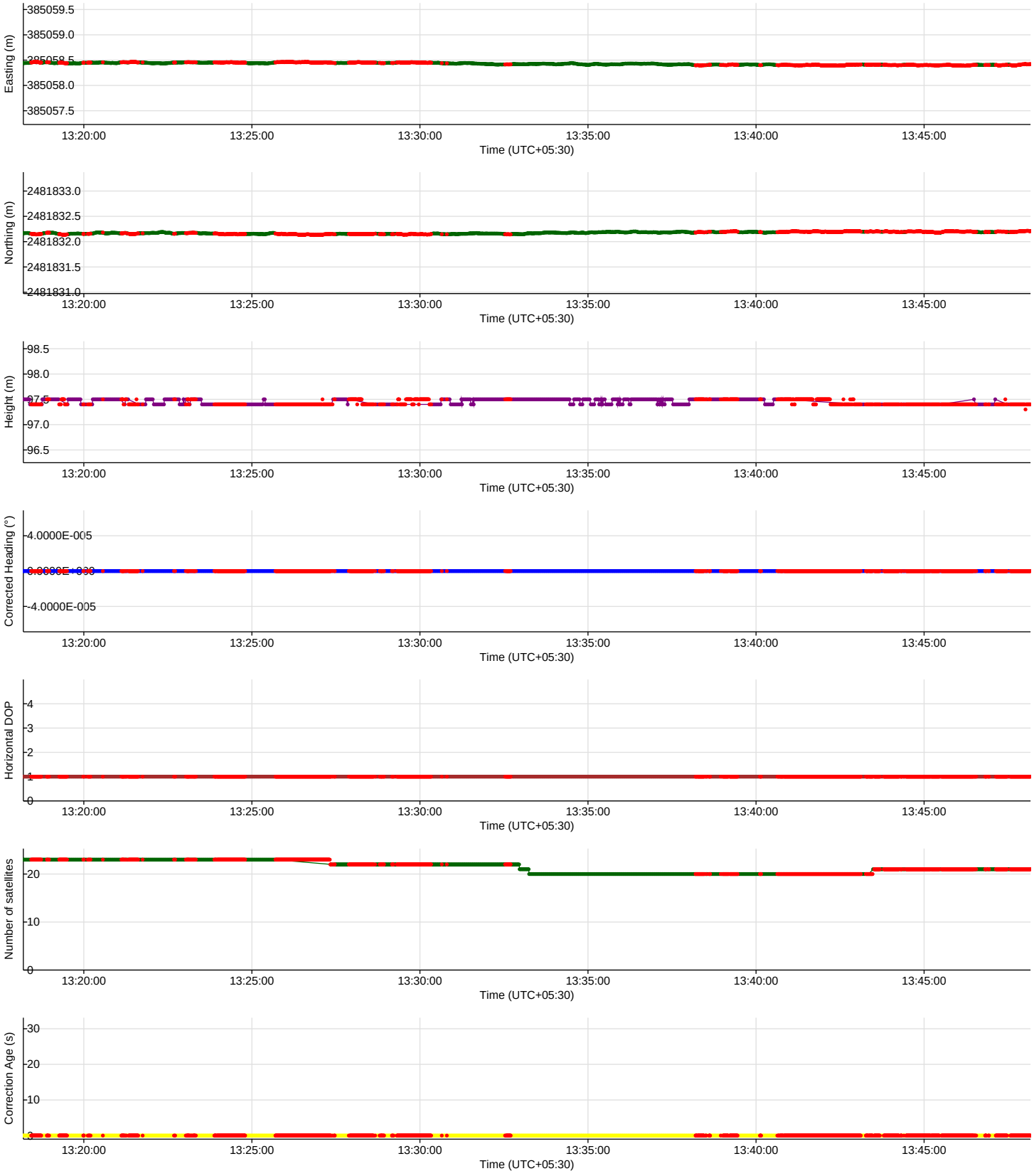
Scatter Plot



Mean Position

	Easting	Northing
Tripod	3,85,058.430m E	24,81,832.172m N

Time Series Plots for Tripod



FUGRO SURVEY (INDIA) PVT. LTD.

Diagram Report of TBM-06

Job No. :	J-HYD-20-174630	**Job Name:**	Bathymetric Survey
Station Name:	TBM-06	**Location:**	Gujarat, West Coast of India
Party Chief :	Arpit Bose	**Job Engineer/Surveyor :**	Mathiazhagan V.
Date of Observation: (Date & Time)	02-04-2021 & 16:16hrs	**End of Observation: (Date & Time)**	02-04-2021 & 16:46hrs

1. Station Name: TBM-06.

Positioning System Verification Results						
World Geodetic System 84, UTM Projection, CM 075° East, Zone 43 North						
Sensor	**Serial No.**	**Starfix.Seis Name**	**Method**	**File Type**	**Mean Differences**	**SD**
TRIMBLE BX992 RECEIVER	025-00009611	PRI_DGPS	Mean position report	FBF	NA	0.02

A= TBM-06 Height is 153.613m above MSL

B= Antenna Height from BM 1.410m (Measured by Tape)

Ellipsoidal height of Antenna= 96.997m

Ellipsoidal Height of BM 96.997m-1.410m=95.587m

C is the center point of BM

Position Of Antenna:-

Latitude: 22°26'19.66822"N, **Longitude:** 73°52'59.52914"E

Easting: 3,85,076.034m E **Northing:** 24,81,824.460m N

Prepared By: Arpit Bose.

BATHYMETRY
MEAN POSITION REPORT

Project ID	J-HYD-20-174630_SUKHI DAM		
Location	GUJRAT		
Client	Govt of Gujarat	**Vessel**	Tripod
Comment			

Session Name: TBM-06-v1 Records Used: 1115 of 1799

Start Time: 02 Apr 2021, 16:16:09+05:30 End Time: 02 Apr 2021, 16:46:08+05:30 Session Length: 00:29:59

Mean Position for Tripod CentreOfGravity		
	WGS 84 / UTM zone 43N	**WGS 84(2D)**
Latitude	22°26'19.66822"N	22°26'19.66822"N
Longitude	073°52'59.52914"E	073°52'59.52914"E
Height	96.997m Ell.	96.997m Ell.
Easting	3,85,076.034m E (SD: ±0.02m)	
Northing	24,81,824.460m N (SD: ±0.01m)	
Height	155.420m Ort. (SD: ±0.05m Ort.)	

Sensors	**Sensor Averages**	**SD**
Heading	0.00°T 0.00°G	±0.0°
Pitch		
Roll		
Depth (Sounder)	0.0m	±0.00m
Depth (Manual)	0.0m	N/A

Arpit Bose
Party Chief
FSINPVT (Fugro Survey (India) Pvt Ltd.)

Deputy Executive Engineer
SUKHI DAM
Govt. of Gujarat

Geodetic Parameters

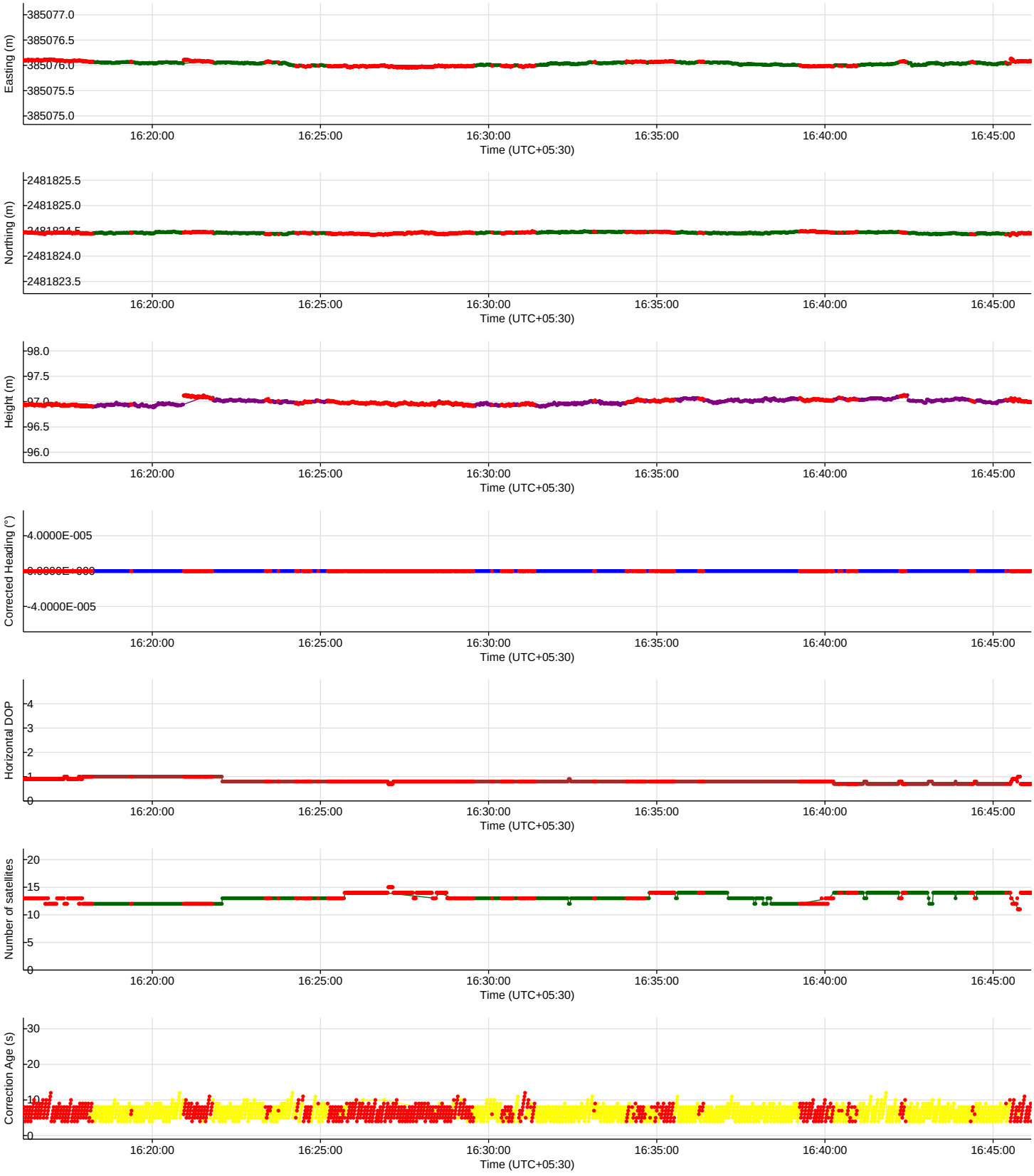
Name : WGS 84 / UTM zone 43N		
EPSG Code	EPSG::32643	
Local Geodetic Datum Parameters		
Datum	World Geodetic System 1984	EPSG::6326
Ellipsoid	WGS 84	
Semi major axis	a = 63,78,137.000 m	
Inverse flattening	1/f = 298.257223563	
Local Projection Parameters		
Map Projection	Transverse Mercator	
Grid System	UTM zone 43N	EPSG::16043
Latitude Origin	00° 00’ 00.000” N	
Central Meridian	075° 00’ 00.000” E	
Scale Factor on Central Meridian	0.9996	
False Easting	500 000 m	
False Northing	0 m	

Scatter Plot

Mean Position

	Easting	Northing
Tripod	3,85,076.034m E	24,81,824.460m N

Time Series Plots for Tripod



Station Name: EDALWADA-TBM

Positioning System Verification With BX-992 Reciever and Spatial Dual						
World Geodetic System 84, UTM Projection, CM 075º East, Zone 43 North						
Sensor	**Serial No.**	**Easting mE**	**Northing mN**	**Latitude**	**Longitude**	**Ellipsoidal height (m)**
TRIMBLE BX992 RECEIVER	025-00009611	385058.568	2481832.21	22°26'19.916"N	73°52'58.916"E	95.665
Spatial Dual	025-272968	385058.43	2481832.172	22°26'19.914"N	73°52'58.911"E	95.806
	Difference	**0.138**	**0.038**	**--**	**--**	**-0.141**

SBES Calibration

SBES Barcheck Correction Table

Project No.	Project Title:	Vessel:	Place:
J-HYD-20-174630	**Bathymetry Survey**	**POLARIS**	**SUKHI DAM**
Date:	Time:	Client:	
03-Apr-21	**14:30**	**GOV. OF GUJARAT**	
Observed By: ARPIT BOSE		Echo Sounder Model and SL. No.	Area Depth
Project No. J-HYD-20-174630		**E20 ECHOTRAC**	**14**

Echo Sounder Settings

Draft HI	Draft LO	Sound Velocity	
		Average	**Upto Depth**
0.3	**0.3**	**1493.02**	**9**
Barcheck Frequency selected	**Survey Frequency:**	Manufacturer's Accuracy	
High 200 KHz	**33 and 200 KHz**	0.10 % of Depth	0.01 m

Observations while lowering			Observations while hoisting		
Bar Depth (m)	ES Reading (m)	Difference (m)	Bar Depth (m)	ES Reading (m)	Difference (m)
1	1	0	10	10	0
2	2.01	-0.01	9	9	0
3	3	0	8	8	0
4	4	0	7	7	0
5	5	0	6	6	0
6	6	0	5	5	0
7	7	0	4	4	0
8	8.01	-0.01	3	3	0
9	9.01	-0.01	2	2	0
10	10	0	1	1	0

	Average	0.00	Average	0.00
	Std. Dev	0.0048	Std. Deviation	0.0000
			Cumulative Average	0.00
			Cumulative Std. Deviation	0.0034

Partychief
Arpit Bose
FSINPVT

Deputy Executive Engineer
Sukhi Dam
Govt. of Gujarat

Location Name:	Sukhi Dam	Date:	24/06/2021	Instrument Name	LYNX
Work:	RTK Observation by Topography Team			Model no.	H6

Station Name		Observation Duration	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Remarks	
SUKHI-TBM	By rover 1	2 sec	385058.394	2481832.283	153.627	XYZ Value generated by RTK of Topography Team, Base Station on Sukhi Dam TBM 06 Fugro Provided XYZ Value used.	Field Photo\IMG_20210624_173909.jpg
SUKHI-TBM	By rover 2	2 sec	385058.421	2481832.279	153.615	XYZ Value generated by RTK of Topography Team, Base Station on Sukhi Dam TBM 06 Fugro Provided XYZ Value used.	Field Photo\IMG_20210624_174448.jpg
SUKHI-TBM	By rover 3	2 sec	385058.414	2481832.288	153.616	XYZ Value generated by RTK of Topography Team, Base Station on Sukhi Dam TBM 06 Fugro Provided XYZ Value used.	Field Photo\IMG_20210624_174645.jpg

		Fugro Provided XYZ Value								Difference With Fugro Provided XYZ Value		
Station Name	Remarks	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Station Name	Remarks	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)	Easting (mE)	Northing (mN)	Local Height w.r.t MSL (m)
SUKHI-TBM	Fugro Provided Value	385058.568	2481832.210	153.615	SUKHI-TBM	Check by Rover 1	385058.394	2481832.283	153.627	0.174	-0.073	-0.012
					SUKHI-TBM	Check by Rover 2	385058.421	2481832.279	153.615	0.147	-0.069	0.000
					SUKHI-TBM	Check by Rover 3	385058.414	2481832.288	153.616	0.154	-0.078	-0.001

Note: SUKHI DAM FRL-147.820m w.r.t MSL (Client Provided), SUKHI-TBM Transferred from FRL.
Note: Base station was on Sukhi Dam TBM 06 (Fugro provided XYZ value), 3 reading taken for 2 sec each on SUKHI-TBM by 3 rovers on pole mounted.

Prepared by Arunabha Chakraborty

Appendix E

Benchmark Descriptions

(8 pages)

Fugro Survey (India) Pvt. Ltd. D-222/30, TTC Industrial Area, MIDC, Nerul, Navi Mumbai Pin - 400 075 (India)	**Station / Bench Mark Description**		
	Job No. :	**J_HYD_20_174630**	**Station Name:**
	Client :	**Govt. Of Gujarat**	
	Location :	Sukhi Dam,Gujarat	**SUKHI-TBM**
	Observed By:	Arpit Bose,Mathiazhagan	
	Date:	02/04/2021	

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station for Bathymetric Survey of Reservoir and Topography survey.

2. Equipment Deployed :- Trimble BX992 Receiver

3. Method Used :- 30 minutes Mean Position for Tripod Centre Of Gravity

Final Coordinates in WGS84 Datum/UTM zone-43N

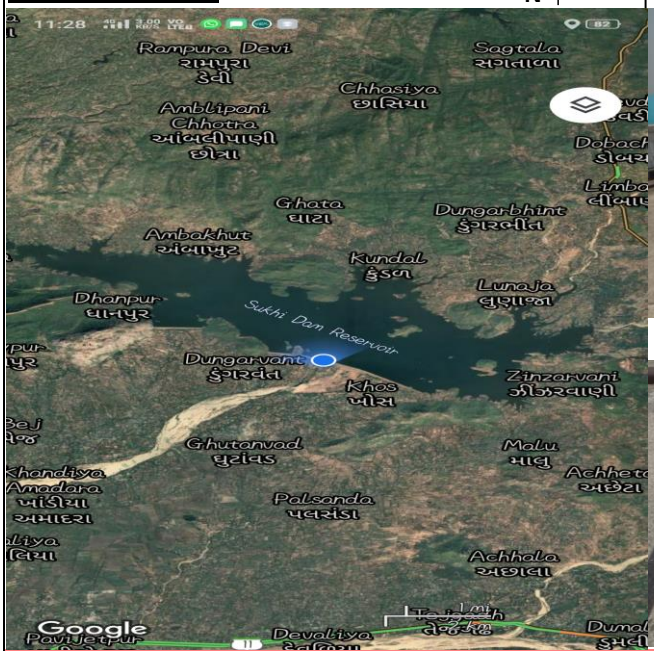
GEOGRAPHICAL COORDINATES:		**UTM COORDINATES:**		CM: 75° E
LATITUDE:	22°26'19.91600"N	EASTING:	3,85,058.568m E	σ = +/- 0.02 m
LONGITUDE :	73°52'58.91618"E	NORTHING:	24,81,832.210m N	σ = +/- 0.02 m
ELLIPSOIDAL HEIGHT:	95.665m	CONVERGENCE :	-0.50293 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE above MSL	153.615 m	

LOCATION & ACCESS : TBM established on Top of Dam of Sukhi Dam which is situated near gate number-1

STATION MARKING : TBM Station is marked with Red paint.

Expected durability of the Station (Years) : 02 years

DETAILED DIAGRAM :



Note:-

Coordinates are measured by DGPS observation.
Client hasn't supplied any X,Y,Z Value
SUKHI-TBM RL value is shifted from FRL(Full Reservoir Level) of the Dam

Client has confirmed that the FRL value(147.820m) is from Mean Sea Level.

Arpit Bose
Party chief (FSINPVT)

Deputy Executive Engineer
Sukhi Dam
GOVT. OF GUJRAT

Fugro Survey (India) Pvt. Ltd. D-222/30, TTC Industrial Area, MIDC, Nerul, Navi Mumbai Pin - 400 075 (India)	Station / Bench Mark Description		
	Job No. :	J_HYD_20_174630	Station Name:
	Client :	Govt. Of Gujarat	
	Location :	Sukhi Dam,Gujarat	SUKHI-TBM
	Observed By:	Arpit Bose,Mathiazhagan	
	Date:	02-04-2021	

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station for Bathymetric Survey of Reservoir and Topography survey.
2. Equipment Deployed :- Trimble BX992 Receiver
3. Method Used :- 30 minutes Mean Position for Tripod Centre Of Gravity

Final Coordinates in WGS84 Datum/UTM zone-43N

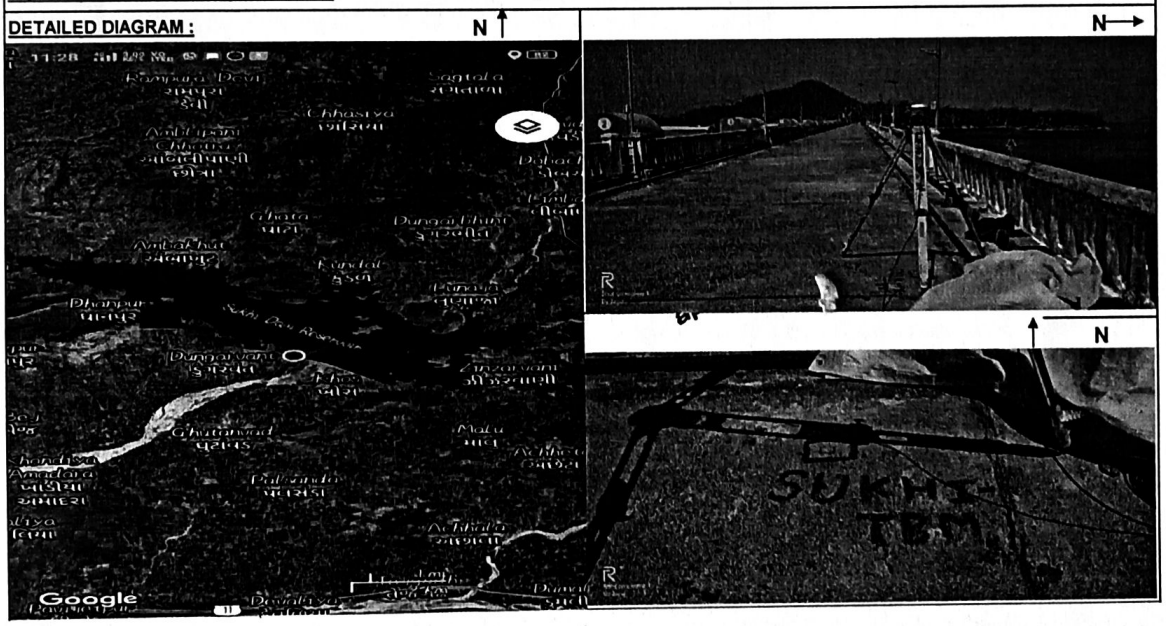
GEOGRAPHICAL COORDINATES:		UTM COORDINATES:		CM: 75° E
LATITUDE:	22°26'19.91600"N	EASTING:	3,85,058.568m E	σ = +/- 0.02 m
LONGITUDE :	73°52'58.91618"E	NORTHING:	24,81,832.210m N	σ = +/- 0.02 m
ELLIPSOIDAL HEIGHT:	95.665m	CONVERGENCE :	-0.50293 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE above MSL	153.615 m	

LOCATION & ACCESS : TBM established on Top of Dam of Sukhi Dam which is situated near gate number-1

STATION MARKING : TBM Station is marked with Red paint.

Expected durability of the Station (Years) : 02 years

DETAILED DIAGRAM :



Note:-

Coordinates are measured by DGPS observation.
Client hasn't supplied any X,Y,Z Value
SUKHI-TBM RL value is shifted from FRL(Full Reservoir Level) of the Dam

Client has confirmed that the FRL value(147.820m) is from Mean Sea Level.

Arpit Bose

Arpit Bose
Party chief
Fugro Survey India pvt ltd

Deputy Executive Engineer
Sukhi Dam
Govt. of gujarat

Fugro Survey (India) Pvt. Ltd. D-222/30, TTC Industrial Area, MIDC, Nerul, Navi Mumbai Pin - 400 075 (India)	Station / Bench Mark Description		
	Job No. :	J_HYD_20_174630	**Station Name:**
	Client :	Govt. Of Gujarat	
	Location :	Sukhi Dam,Gujarat	**TBM-06**
	Observed By:	Arpit Bose,Mathiazhagan	
	Date:	02/04/2021	

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station for Bathymetric Survey of Reservoir and Topography survey.
2. Equipment Deployed :- Trimble BX992 Receiver
3. Method Used :- 30 minutes Mean Position for Tripod Centre Of Gravity

Final Coordinates in WGS84 Datum/UTM zone-43N

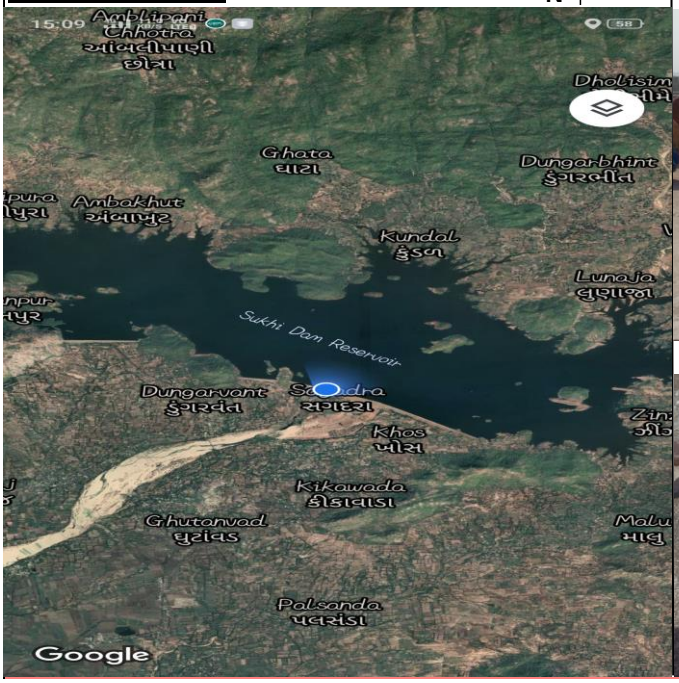
GEOGRAPHICAL COORDINATES:		**UTM COORDINATES:**		CM: 75° E
LATITUDE:	22°26'19.66822"N	EASTING:	3,85,076.034m E	σ = +/- 0.02 m
LONGITUDE :	73°52'59.52914"E	NORTHING:	24,81,824.460m N	σ = +/- 0.01 m
ELLIPSOIDAL HEIGHT:	95.587	CONVERGENCE :	-0.50293 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE above MSL	153.613 m	

LOCATION & ACCESS : TBM established on Top of Dam of Sukhi Dam which is situated near gate number-1.

STATION MARKING : TBM Station is marked with Red paint.

Expected durability of the Station (Years) : 02 years

DETAILED DIAGRAM :



Note:-

Coordinates are measured by DGPS observation.
Client hasn't supplied any X,Y,Z Value
TBM-06 RL value is shifted from FRL(Full Reservoir Level) of the Dam

Client has confirmed that the FRL value(147.820m) is from Mean Sea Level.

Arpit Bose
Party chief (FSINPVT)

Deputy Executive Engineer
Sukhi Dam
GOVT. OF GUJRAT

Fugro Survey (India) Pvt. Ltd. D-222/30, TTC Industrial Area, MIDC, Nerul, Navi Mumbai Pin - 400 075 (India)	Station / Bench Mark Description		
	Job No. :	J_HYD_20_174630	Station Name:
	Client :	Govt. Of Gujarat	
	Location :	Sukhi Dam,Gujarat	TBM-06
	Observed By:	Arpit Bose,Mathiazhagan	
	Date:	02-04-2021	

Brief Description of the Method Adopted

1. Purpose of Establishing the station :- Ref. Station for Bathymetric Survey of Reservoir and Topography survey.
2. Equipment Deployed :- Trimble BX992 Receiver
3. Method Used :- 30 minutes Mean Position for Tripod Centre Of Gravity

Final Coordinates in WGS84 Datum/UTM zone-43N

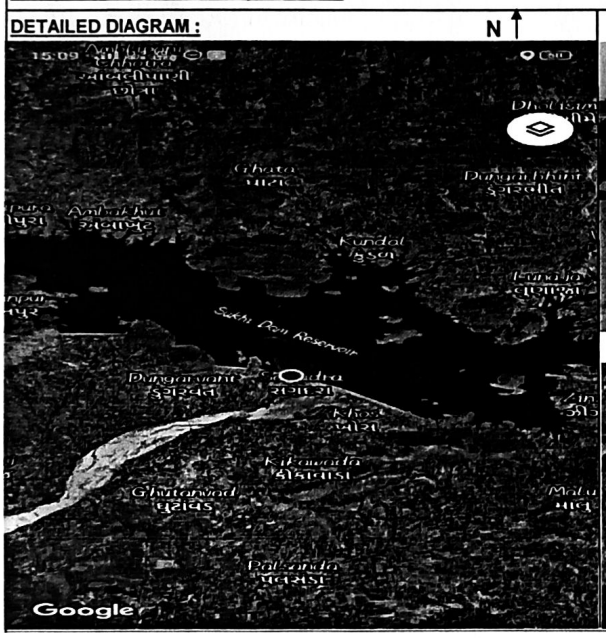
GEOGRAPHICAL COORDINATES:		UTM COORDINATES:		CM: 75° E
LATITUDE:	22°26'19.66822"N	EASTING:	3,85,076.034m E	σ = +/- 0.02 m
LONGITUDE :	73°52'59.52914"E	NORTHING:	24,81,824.460m N	σ = +/- 0.01 m
ELLIPSOIDAL HEIGHT:	95.587	CONVERGENCE :	-0.50293 Degrees	
HEIGHT ABOVE LAT/CD:	NA	TBM VALUE above MSL	153.613 m	

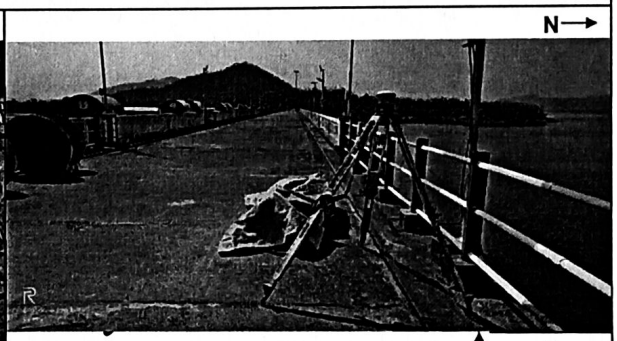
LOCATION & ACCESS : TBM established on Top of Dam of Sukhi Dam which is situated near gate number-1.

STATION MARKING : TBM Station is marked with Red paint.

Expected durability of the Station (Years) : 02 years

DETAILED DIAGRAM :





Note:-

Coordinates are measured by DGPS observation.
Client hasn't supplied any X,Y,Z Value
TBM-06 RL value is shifted from FRL(Full Reservoir Level) of the Dam

Client has confirmed that the FRL value(147.820m) is from Mean Sea Level.

Arpit Bose
Party chief
Fugro Survey India pvt ltd

Deputy Executive Engineer
Sukhi Dam
Govt. of gujarat

FUGRO

REPORT ON RADAR ATG SETUP FOR DATA LOGGING

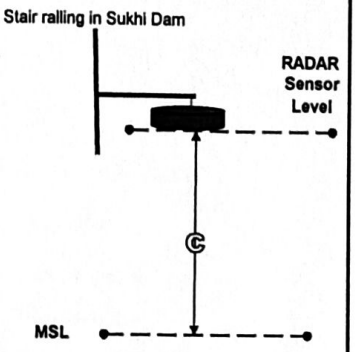
Job No: J-HYD-20-174630	**Job Name:** Singlebeam Bathymetry Survey
Client: Govt. of Gujrat	**Survey Area / Site:** Central Gujrat/Sukhi Dam

ATG Setup, Recovery and Data Download Information

a) ATG Setup on: 01-Mar-21 At: 1200 hrs By: Mathiazhagan V.,Arpit Bose
b) ATG Time set to: UTC Logging Interval set to: 10 min
c) Recovered on: - At: -
d) Data Downloaded on: 02-Mar-21 At: 17:15

ATG Set up & BM Details		Remarks
BM Name :	TBM-06	
BM Source :	TBM-06	
BM to CD (m) :	NA	
MSL to CD (Z_0) (m):	NA	NA
BM to ATG (m) :	0.000	
ATG Value (m) :	151.180	
C-O from ATG Calibration (m):	-0.006	from calibration report
RADAR offset value to be entered in the Tide Master deck unit (m):	151.174	

RADAR ATG Setup Diagram



Key to RADAR ATG Setup Diagram	
RADAR ATG sensor set up above BM	
A : Ht of BM above CD/LAT (m)	NA
B : Ht of ATG Sensor above BM (m)	0.000
C : Ht of ATG sensor w.r.t Mean Sea Level	151.180
D : Ht of MSL Above CD in metres (Z_0)	NA

Note: Value of B should be negetive if RADAR sensor level is below BM

ATG Calibration and Daily Verifications Carriedout at Site

a) Method of Calibration Adopted: Measured the actual height of water-level from the Bottom surface of Radar using pre-calibrated tape.

b) Daily Verifications Carried out:

Results of ATG Calibration

Date & Time	Measured by (m): Tape (C:)	ATG (O:)	C-O (m)
02 Apr/16:40	6.710	-6.713	-0.003
02 Apr/16:50	6.710	-6.713	-0.003
02 Apr/17:00	6.710	-6.722	-0.012
		Mean (C-O)	-0.006

Header Information for the ATG Data Logged

Firmware version: 0741705B8
File Creation Date: 01/04/2021 12:20:33
Battery Level: 5.4
TideMaster S/N: 48693
Station ID: 01
Site info: SUKHI DAM
Calibrated: 17/12/2014
Mode: B3
Pressure units: m
output format: TIDEMASTER
Radar:
Mode: Tide
Firmware: 0745703.c A
Serial Number: 46404
Min limit: 3
Max Limit: 9
Datum: 0
Pre amble: 6
Wind speed units: m\sec
Air Pressure units: mBar
Air Temperature units: DegC

Set up by :	Checked by :
Name: Mathiazhagan V.	Name: Arpit Bose
Engineer	Party Chief

Place: Sukhi Dam
Date: 02-Mar-21

Notes:-

1 ATG Header Info:- a) Copy and Paste ATG Configuration Header File Information from the Logged file.
b) Select Tide File-- Right Click--Open with Text Pad --Copy Header Information -- Paste in Header Information Window

2 ATG Calibration:-

Party Chief
ARPIT BOSE
FSINPVT

Deputy Executive Engineer
Sukhi Dam
GOVT. OF GUJRAT

RECORD OF LEVELLING

(To be used for levelling from an established BM to the Zero of ATG / Tide Pole)

FUGRO

Job No :	J-HYD-20-174630			Client Name :	Govt. of Gujrat
Levelling Equpt Used:	TOTAL STATION TRIMBLE S3			Equipment Serial/Asset No:	91210063
Area/Location Name:	SUKHI DAM			Date of Observation:	02-03-2021
Tide Guage Installed ?:	Yes, ATG RADAR SENSOR			Observer's Name:	Arpit Bose
ATG Zero setup at (m):	0		TBM Level at ATG Site	Prism Holder's Name:	Mathiazhagan V.

Start Point BM Name/ID:	**TBM-06**		
Start Point BM Value (RL) (m):	**153.613m**	FROM	**MSL**

End Point Level Name:	**Bottom of ATG RADAR**		
End Point Level Value (m):	**151.180m**		

SUKHI-TBM to ATG

Station Name	Backsight(SUKHI-TBM)	Fore Sight(ATG)
TBM-06	153.615m	151.180m

ATG to SUKHI-TBM

Station Name	Backsight(ATG)	Foresight(SUKHI-TBM)
TBM-06	151.180m	153.615m

Misclosure =	**0.000**	**meters**	
Adjusted Tide Gauge Height =	**0.000**	**meters**	
Hence, the Zero of Tide Gauge is	**151.180**	**metres Above**	**MSL**

Checked by:Arpit Bose
Surveyor's Name:Arpit Bose
Date:02-04-2021

1.RL Value of station TBM-06 is 153.613m w.r.t Mean Sea Level

Arpit Bose

Party Chief
ARPIT BOSE
FSINPVT

Deputy Executive Engineer
Sukhi Dam
GOVT. OF GUJRAT

LEVELLING RECORD FROM FRL-EDALWADA DAM to EDALWADA-TBM to TBM-05

Job No :	J-HYD-20-174630	Client Name :	GOVT. OF GUJARAT
Levelling Equpt Used:	TOTAL STATION TRIMBLE S3	Equipment Serial/Asset No:	258398 / 273746
Area/Location Name:	SUKHI DAM	Date of Observation:	02/04/2021
Observer's Name:	Arpit Bose	Staff Holder's Name:	Mathizaghan

LEG-1 to SUKHI-TBM		
Station Name	BACK SIGHT(FRL-SUKHI DAM)	FORE SIGHT(SUKHI-TBM)
LEG-1	147.820m	153.615m
LEG-1 to TBM-06		
Station Name	BACK SIGHT(FRL-SUKHI DAM)	FORE SIGHT(TBM-06)
LEG -1	147.820m	153.613m

Note **Vertical distance from FRL to LEG-1 has measured by Total Station**
FRL Value is 147.820m and vertical distance between FRL and LEG-1 is 2.985m so RL of LEG-1 is 147.820m+2.985m=150.805m

So the Station SUKHI-TBM is 153.615m
and the station TBM-06 is 153.613m

NOTE-
1.Client did not provided any XYZ value of BM.
2.Client has provided FRL-SUKHI DAM RL value is 147.820m with respect to Mean Sea Level.
3.Everyday fugro will observe water level from this water level plate.
4.Fugro has transferred RL values w.r.t FRL RL Value which is shown in water level plate.

Party Chief
ARPIT BOSE
FSINPVT

Deputy Executive Engineer
Sukhi Dam
GOVT. OF GUJRAT

LEVELLING RECORD

Job No :	J-HYD-20-174630	Client Name :	GOVT. OF GUJARAT
Levelling Equpt Used:	TOTAL STATION TRIMBLE S3	Equipment Serial/Asset No:	258398 / 273746
Area/Location Name:	SUKHI DAM	Date of Observation:	02-04-2021
Observer's Name:	Arpit Bose	Staff Holder's Name:	Mathizaghan

LEG-1 to SUKHI-TBM		
Station Name	BACK SIGHT(FRL-SUKHI DAM)	FORE SIGHT(SUKHI-TBM)
LEG-1	147.820m	153.615m
LEG-1 to TBM-06		
Station Name	BACK SIGHT(FRL-SUKHI DAM)	FORE SIGHT(TBM-06)
LEG -1	147.820m	153.613m

Note Vertical distance from FRL to LEG-1 has measured by Total Station
FRL Value is 147.820m and vertical distance between FRL and LEG-1 is 2.985m so RL of LEG-1 is 147.820m+2.985m=150.805m

So the Station SUKHI-TBM is 153.615m
and the station TBM-06 is 153.613m

NOTE-
1. Client did not provided any XYZ value of BM.
2. Client has provided FRL-SUKHI DAM RL value is 147.820m with respect to Mean Sea Level.
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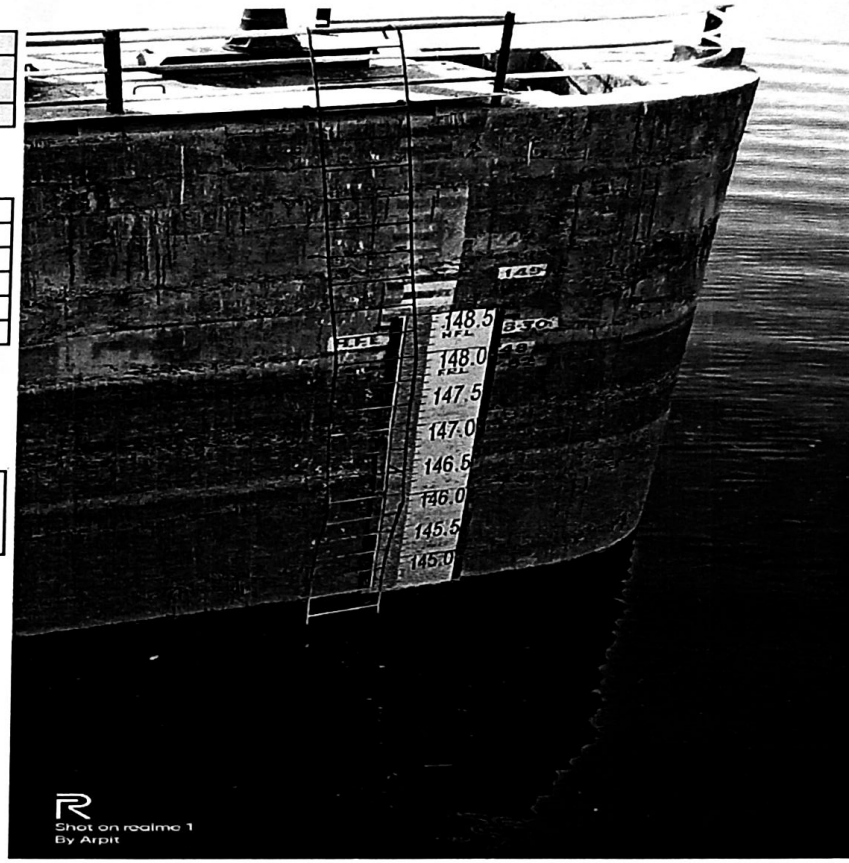
4. Fugro has transferred RL values w.r.t FRL RL Value which is shown in water level plate.



Party Chief
ARPIT BOSE
FSINPVT

Deputy Executive Engineer
Sukhi Dam
GOVT. OF GUJRAT

Appendix F

List of Charts

(1 page)

List of Reports / Documents to be Submitted

Sr. No.	Type of Report / Document	Reporting Schedule	No. of Copies (Hard)	Remarks
1	Survey Procedure (QA Document)	01 December 2020	1	Submitted
2	Mobilisation Report (With Results of Calibration)	26 October 2020	--	Fugro Office copy only
4	Draft Report	30 days from completion of survey	1	Will be submitted after receiving client's comment
5	Final Report on Survey	1 week from receipt of client's comments	10	**This Document**

Details of Charts Accompanying this Report

Details of Charts							
Sl. No.	Charts showing Results of Bathymetry and Topography Survey at Sukhi Reservoir	Sheet No.	Encl. No.	Drawing No.: JHYD-20-174630/WRD/GUJARAT/BS/	Rev. No	HS	VS
1	Reservoir Bed and Topographic Heights	01 of 01	01 of 03	B/01/9707	0	1:12000	-
2	Contour Map of Sukhi Reservoir	01 of 01	02 of 03	B/01/9708	0	1:12000	-
3	Shaded Relief Image Prepared from SBES Data	01 of 01	03 of 03	I/01/9709	0	1:12000	-
Details of Other Deliverables							
1	L-section	Soft copy					
2	C-section at every 100 m	Soft copy					